

COMPETITION OF SICKLEPOD, Cassia obtusifolia L.,
DENSITIES ON SOYBEAN, Glycine max (L.) Merr.,
AT VARIABLE ROW DISTANCES

By

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Competition studies with soybeans, Glycine max (L.) Merr. "Bragg," and sicklepod, Cassia obtusifolia L., were conducted at the Agricultural Research and Education Center of the University of Florida in Quincy, Florida.

Two field experiments were established, one on May 22, 1975, and the other four weeks later, on June 19, 1975, to determine the competitive effects of various sicklepod densities and the influences of soybean row distances on weed dry matter, soybean plant characteristics, yield components and seed yield, and on soil nutrient content.

Control, low, medium, and high sicklepod densities in the first experiment were 0, 25,000, 53,000, and 77,000 plants/ha, respectively; while the second experiment presented control, low, medium, and high sicklepod densities of 0, 36,000, 68,000, and 122,000 plants/ha, respectively.

Three soybean row distance treatments were tested using a constant pattern of 90-, 60-, and 45-cm widths throughout the growing season. Three other treatments, evaluated in a variable pattern, were initially

seeded in 30-cm row widths. Five weeks after planting, an appropriate number of soybean rows were harvested from the 30-cm pattern to establish row distances of 90, 60, and 30-60 cm for the remainder of the season.

In the greenhouse a test was conducted to evaluate the effects of those variables on seed germination and seedling vigor for the next soybean generation.

As a result of full-season sicklepod competition, soybean plants were less branched, set fewer leaves, and presented thinner stems as compared to the control. However, height of soybean plants was not affected by the presence of sicklepod. In one of the two experiments, number of nodes decreased for soybeans under weed competition.

The yield components---number of pods, number of seeds, and seed yield per soybean plant---were all similarly reduced due to weed competition. Seeds per pod were decreased to a lesser extent.

Soybean seed yields per unit area were significantly diminished by increasing levels of sicklepod infestation. While the control produced 3120 kg/ha, the sicklepod densities of 25,000, 53,000, and 77,000 plants/ha reduced seed yields 47, 65, and 73%, respectively.

As soybean row distances decreased, number of branches, number of leaves, and stem diameter of soybeans decreased. However, the height of soybean plants increased with narrowing of row width.

The components of seed yield---number of pods, number of seeds, and seed yield per soybean plant---diminished as row spacing was reduced. Maximum difference between row distances for these attributes was attained for soybean plants under weed-free conditions.

Generally, as row width decreased, soybean seed yield per unit area increased. Specifically, soybeans in 90-cm rows, either in constant or variable row pattern, yielded less than soybeans in 60- and 30-60-cm rows in the variable pattern.

Soil contents of phosphorus, potassium, calcium, and magnesium were not affected by the various levels of sicklepod and soybean populations. Neither the sicklepod densities nor the soybean row distances influenced seed germination and seedling vigor in the next soybean generation.

Sicklepod was a strong competitor with soybeans at all density ranges investigated. Because sicklepod grows taller than soybeans during the reproductive stages of the crop, limited success can be reached by varying row spacing alone. However, this practice is considered an integral measure to complement other methods of sicklepod control.

Compared to constant rows, the soybean cropping system using variable row spacings presents the choice of planting soybeans at close row spacings to provide early competition with weeds and the possibility of obtaining a forage crop after the first month of growth, without any decreases on the final seed yields.

INTRODUCTION

Sicklepod, Cassia obtusifolia (L.), is a summer annual plant belonging to the Leguminosae family. Sicklepod presents light green leaves of two to three pairs of bluntly oval leaflets; yellow flowers borne on drooping stalks in leaf axils; and long, slender, round seed pods with many brownish, angular seeds.

It is a vigorously growing, unpalatable, non-nodulating legume achieving heights of 180 to 210 cm with good moisture and fertility conditions. Sicklepod produces abundant hard seed which remain viable for long periods. It has the ability to emerge from depths as great as 15 cm and also to germinate and emerge throughout the growing season (Barnes and Schrader, 1974; Buchanan et al., 1970).

Sicklepod is a major weed in soybeans in the southeastern United States. Its widespread presence, rapid growth, and prolific seed production, contribute to its importance as a serious problem in soybeans as well as other agronomic crops such as peanuts and cotton (Barnes and Schrader, 1974; Buchanan et al., 1970).

The prevalence of sicklepod in soybeans has increased in recent years with increasing fertilization and use of selective herbicides to replace mechanical weed control. Tolerance to many presently available preplant and preemergence herbicides and adaptability to a wide range of soil fertility and pH levels have contributed to the success of sicklepod as a weed in soybeans, where it remains one

of the most difficult to control weeds (Barnes and Schrader, 1974; Thurlow and Buchanan, 1972).

Weed infestations have been shown by many investigators to generally reduce crop yields. In 1965 it was estimated that annual losses due to weeds and the expense of control measures cost the United States farmers 5 billion dollars. Weeds are one of the major considerations in soybean production. Weeds in soybeans reduce the potential value of the crop approximately 17% annually in the United States (U.S. Department of Agriculture, 1965).

Weeds bring about yield reductions by competing with crops for moisture, nutrients, and light. A principle of crop production is that a given area of land is capable of producing a certain amount of plant dry matter; therefore, the fewer weeds present the greater the crop production (Burnside and Colville, 1964b).

Weed competition is affected by crop species, weed species, production practices, climatic, edaphic, and biotic factors, and weed control measures. Weeds and crops vary in their competitive efficiency and various practices have been proposed to increase the competitive advantage of crop plants (Staniforth and Weber, 1956). Various weed control practices have been tried in an effort to attain maximum soybean yields, but changes in soybean culture also change plant growth habits and yield components (Burnside and Colville, 1964a).

Since weeds are one of the major production problems in the culture of soybeans, possibly some cultural practices presently used on this crop need to be changed to make it more competitive

(Burnside and Colville, 1964b). Competition of desirable plants with undesirable plants frequently provides effective and economical weed control (Robinson and Dunham, 1954).

When soybeans were first introduced into the United States, most farmers attempted to grow them using small-grain techniques. It soon became apparent that soybeans were not good competitors with weeds and that broadcast or drill seedings could not be considered successful. Thus, soybeans became a row crop so that weeds could be controlled with mechanical cultivations (Lovely and Staniforth, 1968).

Soybeans traditionally have been planted in rows from 80 to 100 cm apart, using the equipment and production techniques adapted from corn. Wide rows are essential to accomodate conventional cultivation equipment used for weed control. But weed control in soybeans was adequate if the corn cultivation practices were supplemented with hand pulling of broadleaf weeds (Lovely and Staniforth, 1968). Because cultivation accentuates soil erosion and organic matter losses, other methods of weed control would be more desirable (Robinson and Dunham, 1954).

Researchers have been investigating production techniques to increase profit as well as yield of soybeans. Narrowing the row width has become popular and successful. Agronomic research shows that maximum soybean yields could be obtained with row spacings of 20 or 25 cm. Because of this potential for yield increase and the development of more successful soybean herbicides, some researchers are returning to the drill seeding approach (Lovely and Staniforth,

1968). Increased yields due to narrower rows are partly due to better distribution of soybean plants over the soil surface for more efficient use of available water, light, and nutrients (Burnside and Colville, 1964b).

Usually the pattern of development of the crop canopy is such that for the early stage of development in annual crops only a small percentage of the surface of a field is covered. Considerable space is, therefore, wasted and much of the incoming radiant energy is lost to the crop. Denser stands initially have more rapid growth, because they display more photosynthetic surface per unit area of ground following germination and thus synthesize more material (Williams and Joseph, 1970).

The primary objectives of this investigation were to determine (1) the competitive effects of sicklepod densities on soybean plant characteristics, components of yield, and seed yield; (2) the influence of soybean row distances on sicklepod control, soybean growth habits, yield components, and seed yield; and (3) the response of a soybean cropping system using variable row spacings in providing high early competition with sicklepod, along with the double purpose of supplying forage and seed yields from the same planting.

Secondary objectives were to investigate (1) the effects of the various combinations of sicklepod and soybean populations on soil nutrient content and (2) the influence of sicklepod densities and soybean row distances on seed germination and seedling vigor for the next soybean generation.

LITERATURE REVIEW

Crop-Weed Relationships

Weed Competition

Pavlychenko and Harrington (1934) in their studies of plant communities and plants in homogenous populations have shown that competition is a powerful natural force tending toward limitation or extinction of the weaker competitors. Later Pavlychenko (1949) defined competition as a natural force whereby each living organism tends to attain maximum advantages at the expense of other living organisms occupying the same place.

In studying the competitive efficiency of weeds and cereal crops, Pavlychenko and Harrington (1934) showed that success in competition depends on readiness and uniformity of germination under adverse moisture conditions, the ability to develop a large assimilation surface in the early seedling stage, and a root system with a large mass of fibre close to the surface but with its main roots penetrating deeply. Crops that are able to develop their tops and roots rapidly and to take possession of an area before the weeds attain sufficient development to compete seriously, would be highly efficient competitors. To determine that one plant may have an advantage over another at the early stage of growth is of extreme importance in the final outcome of competition

between them. Generally, a crop which fails to smother the weeds at the early stage cannot do it later.

Hanson et al. (1961) said that the degree of competition between two genotypes depends upon a complex defining aggressiveness and is undoubtedly conditioned by season; and competition effects can be defined only with reference to a competing environment.

Factors of Competition

Pavlychenko and Harrington (1934) and Pavlychenko (1949) pointed out that crops and weeds live in the same environment, and their productive capacities are limited by the moisture, light, nutrients, and space available. Weeds do their damage to the crop in no other way except through competing with them for the essential growth elements--moisture, light, and nutrients. Each group makes a specific claim upon the productive powers of the field. Knake and Slife (1962) reported that the cause of yield reductions where weeds are growing with a crop has been attributed primarily to competition for nutrients, water, and light. But, that carbon dioxide, oxygen, heat energy, and plant exudates have also been suggested as factors to be considered in plant competition.

Pavlychenko (1949) wrote that in most cases all the growth factors, or at least some of them, are present in quantities that are not sufficient to assure the best possible development even of the crop alone. Under these circumstances any weed plant found in the crop uses part of the limited supplies and ultimately reduces the development and yield of the neighboring crop plants. Where the weed infestation is general, the reduction in crop yield is usually proportional to the amount of

moisture, light, and nutrients used by the weeds at the expense of the crop. Knake and Slife (1969) emphasized that there is a given amount of energy available in the form of nutrients, moisture, and light on an area of land. This energy can be used by a specific crop for producing a given amount of dry matter. That portion of the energy used by weeds is not available to the crop and yields are reduced proportionately. Although this general principle may be fairly valid for many situations where competition exists, there is considerable variation in the nature of growth for various weed species and crop plants so that the ratio of weed dry weight to loss in dry weight of crop is not always 1:1.

Pavlychenko and Harrington (1934) reported that competition between crops and weeds is not very obvious and is easily overlooked. Shadbolt and Holm (1956) stressed that it is extremely difficult under conditions of actual competition to determine the role which each factor plays in the injury of the crop. There is seldom only one factor involved, but more often there is a complex interaction between factors.

Staniforth and Weber (1956) recognized that different estimates of crop yield losses might be obtained with varying factors of soil types, soil fertility and available nutrients, moisture supply and availability, and many others.

Radiant energy

Pavlychenko (1949) said that in plant competition light plays a very important part. The weeds, particularly in seedling stage, are smothered with amazing ease, if the crop can effectively shade them. Knake and Slife (1965) in studying the competition between giant fox-tail, Setaria faberfi Harrm. and soybeans reported light readings

that indicate only 2.5 to 3% of light from midday sun reached the area under the soybeans once they were well established. Where the foxtail had started growing with the crop and the foxtail leaves were above or outside the soybeans, then the foxtail made vigorous growth.

Blackman and Templeman (1938) studied the nature of competition between cereal crops and annual weeds, reporting that the light factor is only operative when the weed species is tall growing and the density is high. Weber and Staniforth (1957) confirmed in their studies of weed competition in soybeans that more severe bean yield reductions could be expected from weeds which overtop or seriously shade soybeans than from weeds of approximately the same height.

Shadbolt and Holm (1956) reported that weed competition was found to shade the crop plants to the extent of reducing the light intensity at the crop level by as much as 85% in some instances. It is suggested that this severe reduction in light intensity was responsible for much of the competition which was suffered by the crop plants. The degree of shading and the weight of weeds produced were quite closely correlated. Maximum shading, however, occurred before maximum weed weight was obtained. On the other hand, the degree of shading increased in proportion to the concentration of weeds only during the first few weeks of competition. When the competition remained for periods longer than 4 weeks the degree of shading tended to reach a maximum, independent of the weed concentration. The authors could not determine from the experiment the actual portion of the total injury which was caused by the reduced light intensity.

Moolani et al. (1964) studied competition of smooth pigweed, Amaranthus hybridus L., with corn and soybeans, and found that with

soybeans the dry matter production of pigweed was much greater than the decrease in soybean dry matter, rather than equivalent to it, as with corn growing with pigweed. The fact that pigweed grows taller than soybean offers a possible explanation for the fact that the yield of soybeans was reduced more than that of corn. He concluded that there is very likely a correlation between light intensity and number of flowers or pods.

Knake and Slife (1969) found that with giant foxtail the greatest competitive effect for soybeans appears to occur after the reproductive stage has begun, or after the weeds start overtopping the soybeans or become sufficiently dense to reduce the amount of light the soybeans receive. Such shading may be a major competition factor resulting in a reduction in the number of pods per plant on soybeans. With foxtail overtopping the soybean, the effect of late competition was quite pronounced.

Water

Available soil moisture is a major factor limiting plant growth under many conditions of crop production. As Staniforth (1958) stressed, many of the observed crop yield reductions caused by weed infestations have resulted from the competition of weeds for available soil moisture. And, competition for water often may be modified by the effects of competition for soil nutrients and the shading effects of plants.

Studying the effects of foxtail infestations on soybeans, Staniforth (1958) concluded that bean yield reductions due to competition with foxtail were small when (1) soil moisture was adequate over

the whole season, (2) limited to plant growth over the whole season, or (3) limited by the middle of the season and then adequate to bean maturity. When soil moisture was adequate until the middle of the season and severely limiting from then until bean maturity, yield reductions due to foxtail infestations averaged approximately 14%. Soybean yield reductions due to annual weed infestations averaged 5% when soil moisture conditions during growing season were either adequate for or severely limiting to plant growth. Reductions were also small when moisture was limited early in the season and adequate later.

Staniforth and Weber (1956), verifying the effects of annual weeds on soybeans, considered moisture supply to be the principal environmental factor for which beans and weeds competed during the growing season, since the soil fertility was high in the experiments and the weeds did not overtop and seriously shade the beans. Moisture for plant growth was determined mainly by the amount and distribution of rainfall over the growing season. They found greater bean yield reductions associated with adequate early season moisture and subsequent greater weed growth than with low early season rainfall.

Weber and Staniforth (1957) found that with moderate weed infestations and moisture deficits during the growing season, soybean yield reductions were less than with adequate moisture. Also, Knake and Slife (1962) concluded from their studies of competition of giant foxtail with corn and soybeans that yield reductions in soybeans were greater in years of high rainfall than in a year of low rainfall until mid-season. Moolani et al. (1964) reached the conclusion from competition of smooth pigweed with corn and soybeans that weed competition and

soybean yield reductions were greatest when rainfall in the beginning of the season was high and favorable for weed growth.

Eaton et al. (1973) conducted competition studies with soybeans and Venice mallow, Hibiscus trionum L., and they found that competition was greater when moisture was abundant soon after planting and limited after mid-summer than when moisture was limited immediately after planting and above average thereafter. The most severe weed competition occurred after soybean reproductive growth stages were initiated. Because Venice mallow is a low growing weed, they suggest that most competition between Venice mallow and soybeans is primarily for moisture and secondarily for light energy. Soybeans grown with high weed densities were temporarily wilted 50 to 70 days after planting. Venice mallow exhibited signs of moisture stress at 70 days but was more tolerant than soybeans of intermittent dry spells. Later Eaton et al. (1976) registered that Venice mallow caused more soybean yield losses under dryland than irrigated conditions.

McWhorter and Hartwig (1972) worked with johnsongrass, Sorghum halepense (L.) Pers., competing with soybeans and confirmed that reduced precipitation appeared to increase the competitiveness of johnsongrass.

With sicklepod, Thurlow and Buchanan (1972) reported that in general soybean yields were less affected by a given density of sicklepod in years of high moisture.

Hoveland and Buchanan (1973) reported that seeds of many weed species are commonly assumed to germinate at a lower soil moisture content than crop seeds. Therefore, drought conditions may favor germination of certain weed species and result in a competitive advantage over a crop plant. Such a phenomenon can occur, particularly in sandy soils

which dry out rapidly on the surface in early spring. These workers germinated seeds of certain crops and many weed species with simulated drought and found that most weed species germinated better than soybeans. Sicklepod was one of the most tolerant weed species to simulated drought. Sicklepod germination was delayed by 3 bars osmotic pressure while 6 bars reduced 96-hour germination to 64% and 10 bars to 21%. In contrast, soybean seeds were very sensitive to simulated drought. After 96 hours seed germination was only 31% at 3 bars and nil at 6 or 10 bars, while seed at 0 bar germinated 100%. They point out that this capacity to germinate at relatively low soil moisture, combined with high seed production in many soils, may help account for the rapid establishment of this weed species.

Scott and Oliver (1974) made measurements of the competition for soil water by soybean and tall morningglory, *Ipomoea purpurea* (L.) Roth. The results indicated that soybean removed most of its water from the upper 60 cm of the soil profile with the greatest amount being extracted from the 15-cm soil depth. Morningglory also removed most of its water from the surface. Maximum evapotranspiration (ET) of the competition plots occurred approximately a week earlier than the no-competition plots. The rate of ET during the 2- to 4-week period after planting was generally higher in the competition plots than in the non-competition plots. In the competition plots ET decreased, but water-use efficiency increased as morningglory population increased. Tall morningglory roots were not as concentrated near the top as with soybean roots.

Nutrients

Blackman and Templeman (1938) studying the nature of competition between cereal crops and annual weeds discovered that the presence of weeds depressed the nitrogen and potassium contents of the cereal but did not affect the phosphorus content. And, that additional nitrogen counteracted the effects of weed competition raising both the nitrogen and potassium contents. They concluded that in a year of normal rainfall competition between the crop and the weed is principally for nitrogen and light. In the majority of cases competition is solely for nitrogen.

Blaser and Brady (1950) discussed nutrient competition in plant associations and stated that it has been observed that plant succession in productive meadow mixtures occurs as follows: desirable grasses and legumes--desirable grasses--undesirable grasses and weeds. This succession is commonly associated with depletion of fertility and with mismanagement. The rapidity of plant succession from desirable to undesirable species is probably enhanced by competition for nutrients among the species. Evidence for this is indicated by the relative intake of potassium by different species, i.e., weeds, grasses, legumes. The high absorption of potassium by weeds adds to the significance of nutrient competition among weeds and crop plants. They concluded that the increased yields of crops as a result of eliminating weeds may be associated with nutrient conservation as well as moisture conservation.

Vengris et al. (1953) determined the chemical composition of weeds and accompanying crop plants, and they found that weeds are important competitors with cultural plants for N and K, which are often limiting

factors in crop production. Weeds are able to accumulate considerable amounts of these nutrients at the expense of cultural plants, thereby reducing their yields, especially when these elements are not supplied in liberal amounts. High phosphorus accumulation in weeds indicates that they are competing with cultural plants for this element, especially when quantities of available soil P are inadequate. On the other hand, high P level in weeds, even with low levels of available P in the soil, indicates an ability on the part of many weeds to utilize forms of soil phosphates which are relatively unavailable to many cultural plants. Also, weeds in general and especially dicots have a rather high content of minerals and proteins. Weeds are able to accumulate about as much Ca and Mg as the legumes and as large or larger amounts of K as the grasses. Weeds in general are comparatively rich in minerals.

Staniforth (1962) found that weed growth and resulting soybean yield reductions were greater following applications of 75 or 150 kg/ha of nitrogen the previous year. The responses of weeds to residual fertilizer applications with accompanying decrease in soybean yields indicate potentially greater weed problems when soybeans following heavily fertilized corn in the rotation.

Creel et al. (1968) affirmed from their studies that sicklepod response to N, P, and K levels was similar to cotton and higher than that of soybeans. The relative growth of cotton and sicklepod was decreased comparably by reducing N, P, and K levels. Therefore, changing the level of fertility at which the seedlings are grown is not likely to change the relative competitiveness of these two species. Sicklepod also was able to grow well under a wide range of soil pH (from 3.2 to 7.9), an ecological advantage attributed to tropical legumes in general.

The optimum pH for sicklepod was in the range of 5.5 to 6.0.

Teem et al. (1974) investigated the primary root elongation of sicklepod, reporting that it was reduced 62% at pH 5.5 as compared to pH 6.5. Although rate of root elongation was less at pH 5.5 or 5.1, roots continued to elongate throughout the experiment and appeared to be fairly tolerant to a wide range of soil pH. Competition between weed and crop species is often critical during the seedling stage. Generally, the most rapidly established species will have a competitive advantage and will seriously delay growth of other species. Root growth rate is critical in the establishment of one species and the failure of another.

Hoveland et al. (1976) investigated the response of weed and crop species to soil phosphorus and potassium. They found that sicklepod, among others, was the most tolerant to low soil P. The phosphorus levels ranged from 8 to 95 kg/ha and potassium levels from 40 to 213 kg/ha. At the 22 kg/ha level of P, growth of sicklepod was only 60% of growth at the 90 kg/ha level. Soybean growth was reduced only 20% at the 8 or 22 kg/ha P level, much less than any of the warm-season weed species. Sicklepod made normal growth at the medium K level; however, growth of this species was 80% at the low K level. Soybean growth was not affected by level of soil-test K. Generally, weeds were more sensitive to low soil-test P than to low soil-test K. Crop species were generally less sensitive to soil-test P and K than were the weed species. They considered that population shifts have been attributed to certain herbicides in some cropping systems; and that it is also conceivable that P and K levels affect weed populations in the field and indirectly weed control programs.

Losses and Damages Caused by Weeds

Seed yields

Weeds have long been recognized as a source of considerable loss in crop production. Investigations of the competitive effects of annual weeds on soybeans have emphasized the extent of soybean yield reductions.

Burnside and Colville (1964b) studied soybean yields and weed yields under combination of several treatments, and for each 100 kg/ha of weeds present an average soybean yield reduction of 70 kg/ha was measured.

Burnside (1973) in another study found that soybean yields were inversely related to weed yields. Weed growth reduced soybean yields 53% on untreated plots.

Staniforth and Weber (1956) reported about the effects of annual weed infestations on the growth and yield of soybeans over a 3-year period. In a total of 15 experiments, yield reductions averaged approximately 10% of weed-free beans, when weeds were present for the entire season. Yield reductions were roughly proportional to the amount of growth made by weeds. The bean yield reduction in kg/ha resulting from each 45 kg of weed dry matter at maturity varied from 25 to 35 kg/ha, depending on season, location, and weed species.

Knake and Slife (1962) investigated the competition of giant foxtail with soybeans. They had densities consisting of 54, 12, 6, 3, 1, 0.5, and no foxtail per 0.3 m of crop row in a 3-year study. Yield reductions for the heaviest stand of foxtail averaged 28% for soybeans. And, the increase in foxtail dry matter was proportional to the decrease

in the dry matter from the crop. Later Knake and Slife (1965) reported 27% soybean yield reduction from foxtail that began growing with the crop and was left to maturity.

Nave and Wax (1971) reported that in their studies a giant foxtail infestation of one plant per 0.3 m in 75-cm rows reduced yield of soybeans by 13%. And, also a reduction in soybean yield of 25 to 30% resulted from one smooth pigweed per 0.3 m in 75-cm rows.

Staniforth (1965) found that differences in the competitive effects of three major species of foxtail on soybeans were due primarily to differences in the mature plant yields of the foxtail species. Giant foxtail grew more vigorously and caused greater soybean yield reductions than did either yellow foxtail, Setaria lutescens, or green foxtail, Setaria viridis.

Moolani et al. (1964) reported that the 3-year average reduction in soybean yields resulting from the heaviest stand of smooth pigweed they had was 55%. Comparing the weed-free treatment with the band of weeds in the row, the yield reductions were 49, 87, and 21%, respectively, for a 3-year period. Pigweed grew taller than soybeans and the dry weight of crop plus pigweeds was 1.3 times that of weed-free soybeans. Even though the number of weeds for a given treatment was held constant the amount of weed dry matter produced varied considerably with the season.

Berglund and Nalewaja (1971) investigated the competition of wild mustard, Brassica kaber (D.C.) Wheeler, at 0, 0.5, 1, 2, 4, 8, and 16 plants per 0.3 m of row in soybeans during 2 years. Soybean seed yield reductions ranged from 21% with 1 to 90% with 16 wild mustard plants per 0.3 m of row. Berglund and Nalewaja (1969) also reported that

soybean seed yields decreased as wild mustard densities increased. Yield reductions at one location averaged over two row spacings, and seeding rates were 30, 36, 42, 50, and 51% with 1, 2, 4, 8, and 16 wild mustard plants per 0.3 m of row, respectively. At another location, reductions were 62, 72, 80, 89, and 93% with 1, 2, 4, 8, and 16 wild mustard plants per 0.3 m of row, respectively. In some plots with wild mustard infestations of 8 and 16 plants per 0.3 m of row, soybean plants were nearly eliminated by the competition.

According to Wilson and Cole (1966), Ipomea purpurea (L.) Roth and Ipomea hederacea (L.) Jacq. significantly and equally reduced soybean yields. Where morningglories were not removed, yields were reduced 52%. The yield decreased at a slower rate as the number of morningglory plants was increased. Oliver (1974) studied competitive effects of three tall morningglory densities on soybean for 2 years. Full season competition reduced soybean yields 43, 57, and 68% for the 16,250 or 1.7/m; 32,500 or 3.3/m; and 65,000 or 6.7/m tall morningglory populations per ha, respectively.

Barrentine (1974) studied the competitive effects of common cocklebur, Xanthium pensylvanicum Wallr., on soybeans during 3 years. Full-season competition by common cocklebur at 3,300, 6,600, 13,000, and 26,000 plants/ha reduced soybean seed yields on the average 10, 28, 43, and 52%, respectively.

Thurlow and Buchanan (1972) investigated during 3 years the competitive effects of sicklepod on soybeans. They found that soybean yield was a linear function of the weed densities studied (0 to 15 weeds/m²). Densities of 7.7 weeds/m² reduced soybean yield 19 to 32% and 34 to 35% on the two soils, respectively. The regression coefficient of weed

density (weeds/m²) on bean yield (kg/ha) was -95, across soils and years studied. The weight of weeds at harvest was also inversely correlated with soybean yield. Weight of sicklepod growing in the soybean at harvest was a more precise indicator of soybean yield than was the number of sicklepod plants present per unit area. The regression coefficient for dry weight of weeds at harvest on soybean yield varied from 0.269 to 0.376 kg/ha of soybeans for each kilogram per hectare of dry weight of sicklepod.

Buchanan and Burns (1971) reported on weed competition in cotton at two locations and during 4 years, through establishment of specific densities of sicklepod. Competition from sicklepod caused cotton yield reductions at densities as low as eight weeds per 7.3 m of row. Sicklepod at eight weeds per 7.3 m of row reduced yields from 10 to 23% on one location and approximately 40% on the other location. At the highest density, 48 sicklepod plants per 7.3 m of row, yields were reduced 45 to 65% and approximately 80% on the two locations, respectively.

ThurLOW and Buchanan (1972) considered that in general, sicklepod is more effective in reducing yield of seed cotton than in reducing yield of soybeans. Less competition from comparable weed densities in soybeans than in cotton can probably be accounted for by the shorter growth cycle of soybeans; there is less time for the weeds to exert their competitive effect.

Yield components

Weber and Staniforth (1957) said that weeds had little effect on seed size of soybeans in the experiment they conducted.

Hammerton (1972) found that reduced seed production per plant was the main cause of the yield reductions of soybeans due to weed competition, but seed size (weight) was also affected.

Burnside and Colville (1964a) reported that reduced weed yields increased the number of pods per soybean plant. Also, treatments which controlled weeds increased the number of seeds per pod, and treatments that did not adequately control weeds showed reduced numbers of seeds per plant. Weight of 100 seeds was not affected by the weeds. Treatments that did not adequately control weeds increased protein percentage of soybean seed, but protein production per area was reduced due to reduced soybean yields. Oil percentage of seed was reduced on plots receiving no weed control treatment as was total soybean yields.

Nave and Wax (1971) observed 25% more beans per plant in the weed-free plots than in the weedy plots. Knake and Slife (1962) reported that as stands of foxtail increased, there was a decrease in number of soybean pods. But, there was little or no significant effect on oil or protein content of beans, weight of 100 beans, or number of beans per pod.

Staniforth (1958) found only a slight reduction in the number of bean seeds per pod when competition from foxtail was severe. Seed weight of beans was reduced when yield reductions due to foxtail were severe, but not enough to account for all of the observed yield reductions. The combined effects of slightly fewer seeds set and an appreciable number of very light seeds probably accounted for the bean yield reductions which resulted from competition due to foxtail.

Moolani et al. (1964) registered that as stand of pigweed increased, there was a decrease in soybean pods per plant.

With wild mustard, Berglund and Nalewaja (1969) reported that pods per soybean plant, seeds per soybean pod, and seeds per soybean plant decreased as densities of the weed increased. Berglund and Nalewaja (1971) also observed that soybean seed oil content, iodine value of soybean oil, and soybean seed weight were not influenced by wild mustard competition.

Eaton et al. (1973) studied competition of soybeans with Venice mallow finding that weed competition affected the number of pods per soybean plant more than any other seed-yield component. Differences in soybean seeds per pod and seed weight may have contributed to yield variability, but the number of seeds per pod was not highly related to weed weight. Soybean seed weight was influenced by weed density, being correlated negatively and highly significantly with dry weight of weeds.

Eaton et al. (1976) investigated competition of velvetleaf, Abutilon theophrasti Medic., prickly sida, Sida spinosa L., and Venice mallow in soybeans. Weed competition reduced the number of soybean pods per plant more than other soybean-yield components, although seeds per pod and seed size have been reduced by weed competition. Velvet-leaf seeded simultaneously with soybeans reduced the number of soybeans per pod. Soybeans planted simultaneously with weeds produced heavier seeds than weed-free soybeans. The increase in seed weight resulted almost entirely from velvetleaf seeded simultaneously with soybeans. When soybean pods per plant were reduced by velvetleaf, heavier seeds were produced; but increased seed weight did not compensate for loss of pods because severe yield losses occurred.

Buchanan and Burns (1971) reporting about sicklepod competition in cotton found that boll weight was reduced to some extent in some of the weed competition treatments, but this could not account for the yield reductions. Yield reduction was primarily the result of a decrease in number of bolls per matured cotton plants. The effect of sicklepod competition on cotton seed weight was analogous to the effect of boll weight. Percentage lint was not affected by sicklepod competition, and likewise fiber properties were not affected.

Barrentine (1974) reported that none of the treatments of common cocklebur competition in soybeans affected the percent oil, percent protein, or grade of soybean seed.

However, Burnside (1973) observed from his studies that plant debris was greater in seed from weedy plots, thus reducing seed quality.

Anderson and McWhorter (1975) determined the effects of common cocklebur on soybean grade by analysing samples of soybean seed. Foreign matter in soybean seed samples was 0.7% with 100% cocklebur control and 5.1% with no cocklebur control. At least 70% cocklebur control was required to avoid deductions from gross harvest weights due to seed moisture levels exceeding 13%. Small discounts for damaged kernels were assessed when cocklebur control was less than 40%. A slight tendency was noted for test weights to increase and the percentage of split kernels to decrease as cocklebur control increased. With 100% cocklebur control, the estimated U.S. soybean grade was 1.3. Failure to control cocklebur resulted in a predicted grade of 3.9.

Morphology and growth

Studies by Weber and Staniforth (1957) revealed that weeds had little effect on maturity, lodging, and height of soybeans. Knake and Slife (1962) confirmed that there was little or no significant effect on height of soybeans as the stand of foxtail increased. McWhorter and Hartwig (1972) also concluded that heavy growth of johnsongrass and common cocklebur had no appreciable effect on lodging or height of soybean plants. Heavy competition from johnsongrass or common cocklebur had no effect on the date that soybeans began flowering or when they matured.

However, Burnside and Colville (1964a) found in their experiments that soybean heights on plots receiving no weed control treatment were significantly shorter than other soybeans, probably due to increased weed competition. Staniforth and Weber (1956) reported that the presence of weeds delayed maturity about 1 day, decreased height about 5 cm, and increased lodging of soybeans 2 to 6%. Moolani et al. (1964) also observed that as stand of pigweed was increased, there was a decrease in the height of the crop. Wilson and Coie (1966) reported that two species of morningglory significantly and equally reduced soybean plant height and increased lodging and the difficulty of harvesting. Damage to soybeans increased as the population of morningglories increased.

Berglund and Nalewaja (1969 and 1971) conducted experiments on wild mustard competition in soybeans finding that soybean plant height decreased as wild mustard densities increased. Height of the lowest soybean pod was not influenced by wild mustard competition at

one location; while, at the other location, height of the lowest soybean pod increased.

Eaton et al. (1973) reported that Venice mallow competition reduced soybean height significantly. With height reduced, the soybean leaf area was shaded by the low-growing weeds. Likely, the reduced effective leaf area caused the soybeans to utilize a greater proportion of available energy for general maintenance, so less energy could be used to produce pods and seeds.

Eaton et al. (1976) investigated competition of velvetleaf, prickly sida, and Venice mallow in soybeans, finding that all three weed species reduced the number of nodes per soybean plant, and reductions were most severe when weeds were seeded simultaneously with soybeans.

Buchanan and Burns (1971) discovered that height and stem diameter of cotton plants responded similarly each year to competition from sicklepod. At one location, neither plant height nor stem diameter was significantly reduced by any density of sicklepod. At the other location, however, plant height was reduced by densities of sicklepod greater than 24 weeds per 7.3 m of row (96 cm apart). Stem diameter was reduced by all densities of sicklepod at this location. Maximum stem diameter reductions of cotton occurred at the higher weed densities.

James et al. (1974) studying competition of common cocklebur with soybeans found that of the soybean measurements taken, leaf area and dry weight were the most affected by weed competition. Also, crop growth rate and net assimilation rate decreased with increased competition.

Lambert and Oliver (1974) evaluated the competitive effects of spurred anoda, Anoda cristata (L.) Schlecht, on soybeans. Soybean leaf area per plant 8 weeks after emergence was reduced by 50% at 1, 2, and 3 spurred anoda per 0.3 m of row, with soybean leaf area in the 0.5 weed per 0.3 m of row being no different than the check. Soybean lodged severely at 9 weeks after emergence.

Crop establishment

Creel et al. (1968) discovered that a water extract of sicklepod tops inhibited germination of cotton and oat. Final germination of cotton was reduced to 2% of the water check by extracts while germination of oat seed was reduced to 61%. Germination of corn and clover seed was delayed by the extract. Germination of sicklepod, soybeans, and wheat was not affected. Seedling growth of all species except soybeans and sicklepod was reduced by the extract. Seedling growth was reduced 80% for wheat. Incorporation of sicklepod residues in soil reduced germination of cotton seed. There was evidence in nutrient cultures that sicklepod released a phytotoxic residue from its roots, reducing growth of cotton but having no effect on soybeans.

Harvesting efficiency

Hauser et al. (1975) reported that unsuppressed broadleaf weeds may tower 2 to 3 m over peanuts at harvest, interfering with harvesting and damaging equipment. Sicklepod, for example, grows slowly early in the season, but may reach height of over 2 m by the time the peanut fruit is maturing.

Weber and Staniforth (1957) determined that heavy weed infestations in soybeans delay and decrease ease of harvesting and increase seed cleaning and storage difficulties.

Wilson and Cole (1966) found no significant differences in the amount of damage resulting from competition from Ipomea purpurea, I. hederacea, or both species together in soybeans. Both species, alone and in combination, significantly reduced yields and increased lodging and the amount of difficulty encountered in harvest operations.

Nave and Wax (1971) reported that harvesting before weeds were desiccated resulted in significant threshing and separating losses in soybean. Stubble, lodging, and stalk losses were more than double in the pigweed and foxtail plots when compared to the weed-free plots after weeds were desiccated by frost.

Burnside et al. (1969) determined that widely varying weed densities that had been desiccated by freezing did not reduce combine efficiency (gathering plus threshing losses) in harvesting soybeans. Average combine gathering loss of soybeans was 16% while the average threshing loss was less than 3%. The high gathering losses in the study were due partly to delayed combining to allow the weeds to be desiccated by freezing temperatures. Weed yields were negatively correlated with soybean yields and combine gathering and threshing losses. High weed yields were correlated with low combine harvesting losses because weeds reduced soybean lodging, weeds reduced soybean shattering during cutting, and weeds tended to sweep shattered soybeans on the combine platform and into the cylinder. If weeds were not allowed to be desiccated by freezing, they definitely would reduce harvesting efficiency. Also, large

amounts of desiccated weeds increased the amount of foreign matter in the grain tank which had to be separated before yields were determined.

Critical Period of Competition

Blackman and Templeman (1938) stated that the critical period of competition is confined to the early stages in the development of cereal crops. Weeds capable of making rapid growth during this period depress the crop yield to a greater extent than those which develop later in the season.

Shadbolt and Holm (1956) also found that weed competition during the early part of the season caused many adverse effects on vegetable crops. The period from emergence to $4\frac{1}{2}$ weeks was a critical period on competition. A further increase in the length of the period of competition produced less than a proportionate increase in the total injury.

Hammerton (1972) found that controlling weeds until 6 weeks after emergence gave a yield of soybeans only 85% that of the clean-weeded control treatment. Delaying weeding until 3 or 6 weeks after emergence gave yields of 89 and 69% of the control, respectively.

Wheatley and Cole (1967) reported that the highest yields were obtained by removing the weed competition from soybeans every week throughout the growing season, every 2 weeks throughout the growing season, and 4 weeks after planting with supplemental hoeing every 2 weeks the remainder of the season, respectively. When weeds were removed only once during the growing season, 6 weeks after planting, the yield was significantly less than the maximum yield obtained.

Burnside (1972) concluded that removing weeds the first 3 weeks after planting soybeans eliminated 74% of the weeds present in the weedy check plots. His results show that early weed control can be effective by eliminating weed growth during the critical early stages in the life cycle of soybeans when they are most vulnerable to competition from weeds.

Knake and Slife (1965) seeded foxtail 3 weeks or later after the soybeans were planted and concluded that these treatments did not cause yield reductions. Soybeans produced shade, and foxtail from the 3-week or later seedings produced little or no dry matter or seed. Where giant foxtail in the row can be controlled by herbicides or other means for 3 to 5 weeks after soybeans are planted, the soybeans can compete sufficiently with later germinating foxtail to prevent yield reductions.

Ambrose and Coble (1975) studied competition of fall panicum, Panicum dichotomiflorum Mich., on soybeans and determined that competition for 2, 4, 6, 8, 10, and 19 weeks after soybean emergence reduced yields 1, 7, 9, 12, 16, and 40%, respectively. Fall panicum removed during the first 10 weeks after emergence resulted in no significant yield reduction. Weed-free durations for 0, 2, 4, 6, 8, and 10 weeks after emergence reduced soybean yields 40, 10, 3, 1, 0, and 0%, respectively. Soybean yields were not reduced significantly if weed-free 2 or more weeks after emergence.

Berglund and Nalewaja (1969 and 1971) investigated competition between soybeans and wild mustard finding that soybean seed yields were not significantly reduced by wild mustard competition for 1, 2, and 3 weeks after emergence. Wild mustard removal which was

delayed for 7 weeks after emergence caused a reduction in the yield of soybean seed by 31% and no further reductions occurred with longer periods of wild mustard competition. Wild mustard sown 3 to 6 days prior to soybeans reduced soybean seed yield by an average of 80%. However, wild mustard sown 3 or 6 days after soybean reduced seed yield only 5 to 7%.

Eaton et al. (1973) reported that the duration of Venice mallow competition affected soybean yields similarly in 2 years. Soybean yields declined with extended competition the first year but did not differ from the control until at least 45 days of weed competition. In the second year, 50 days of competition significantly reduced yields. Soybean yields declined sharply with 50 days or more of competition and as much as 73% with 85 to 110 days of competition.

Eaton et al. (1976) studied competition of velvetleaf, prickly sida, and Venice mallow in soybeans. Weeds that emerged with soybeans reduced yields 1010 kg/ha. Weeds planted later reduced yields 480 kg/ha but weeds planted 20 to 40 days after soybeans did not significantly reduce yield. All three weed species were most competitive when soybeans and weeds were established simultaneously.

Wilson and Cole (1966) found that control of morningglories was needed for 6 to 8 weeks from the date of soybean planting. Morningglory removal before 6 to 8 weeks from the date of planting permitted growth of new morningglories which reduced height, increased lodging, made harvesting operations difficult, and reduced yield. When morningglories were permitted to remain longer than 6 to

8 weeks after planting, soybeans never recovered from the early competition. Removal every 2 weeks or removal of morningglories at 6 to 8 weeks after planting, permitted maximum soybean yields and soybean plant characteristics were not seriously affected.

Oliver (1974), reporting on competition of tall morningglory with soybean, found a significant soybean yield reduction after 12, 10, and 6 weeks of competition for the 16,250, 32,500, and 65,000 morningglory populations per hectare.

Barrentine (1974) determined that competition from common cocklebur for 4, 6, 8, 10, 12, and 16 weeks after soybean emergence reduced soybean seed yields 10, 36, 40, 60, 80, and 80%, respectively. A reduction in soybean stand occurred after 12 or more weeks competition, and increase soybean plant height occurred after 10 or more weeks competition. When common cocklebur was removed during the first 4 weeks after soybean emergence, no further removal was required to obtain maximum soybean yield.

ThurLOW and Buchanan (1972) reported that soybean yields were reduced in some instances when sicklepod was allowed to compete for as little as 4 weeks. If weeds were removed at 2 to 4 weeks after soybean emergence, no further weed removal was needed for maximum yield of soybeans in 105-cm rows. It appears that soybeans will withstand approximately 4 weeks of early weed competition under most conditions without causing deleterious effects on yields.

Hauser et al. (1975) determined that peanut yields were not reduced when the crop was maintained free of sicklepod for 4 weeks after crop emergence and when vigorous crop growth was maintained for the remainder of the season. Sometimes weed-free maintenance

for only 2 weeks resulted in near-normal yields. Conversely, this weed had to compete with peanuts for more than 10 weeks before crop yield was reduced.

Buchanan et al. (1976) reported that when peanuts were not kept weed-free, a single cultivation 4 weeks after emergence increased yields substantially over those of non-cultivated peanuts. Cultivation had no effect, however, when peanuts were maintained weed free for 4 or 8 weeks. Peanut foliage, which was released from weed-free maintenance at 8 weeks but then competed with sicklepod until harvest, reduced the green weight of sicklepod 95 to 98%.

Barnes and Schrader (1974) obtained results that indicate that sicklepod would be a stronger competitor early in the season on light soils than in heavier soils. Sicklepod emergence was more rapid for the loamy sand than for the fine sandy loam and the clay loam soils studied.

Spatial Weed Placement

Eaton et al. (1976) in their experiments obtained soybean yield reductions regardless of weed placement in or between soybean rows.

Wilson and Cole (1966) determined no significant difference between treatments whether morningglories were removed between the rows (32% reduction) or in the rows (35% reduction).

Eaton et al. (1973) in their studies concluded that one Venice mallow per 7.5 cm of soybean row (75 cm apart) reduced soybean seed yield 630 kg/ha after 85 days competition. Thirty to 40-cm weed bands in and between soybean rows reduced yields 270 to 650 kg/ha with 35 to 40 days of competition. A natural stand of 215 Venice

mallow plants/m² reduced soybean yield 450 kg/ha after 30 days of competition, and competition up to 110 days reduced yield as much as 1490 kg/ha.

James et al. (1974) conducted studies to determine the distance of influence of common cocklebur on soybeans. Soybean seed yield was reduced by 0, 10, 25, and 47% at 75 to 105, 45 to 75, 15 to 45, and 10 to 15 cm, respectively, from the cocklebur plant when compared to the control plot.

Thurlow and Buchanan (1972) found sicklepod more competitive when grown 15 to 30 cm from the drill than in the drill (102 and 107 cm apart on each of two soils). These results suggest that soybeans are highly competitive with sicklepod, especially when it is grown in the soybean row.

Cultural Practices for Weed Control

Cultivars

Eaton et al. (1976) emphasized that different soybean cultivars vary slightly in abilities to compete with weeds, which suggests cultivar selection could slightly reduce yield losses due to weeds.

Staniforth (1962) concluded that the responses of the four soybean varieties in his experiments were the same under all variations of soil fertility, bean stand, and seasonal effect encountered. The maturity range of varieties included early, adapted, and late.

Wax and Pendleton (1968) made observations to estimate when two soybean varieties formed a complete canopy over the ground surface. One variety formed a canopy 5 days later than the other at all row spacings tested.

Burnside (1972) tested the competitiveness of 10 soybean cultivars to weeds, especially to tall waterhemp, Amaranthus tuberculatus (L.) Beauv., and green foxtail. "Wayne" soybeans were the poorest suppressor of weeds showing an average weed yield significantly higher than that of any other cultivar. However, "Wayne" had the lowest plant population of all soybean cultivars studied which would reduce its ability to compete with weeds. There was not a great difference in average weed yields among the other nine varieties, but the three showing the lowest weed yields were "Harosoy 63," "Shelby," and "Corsoy."

McWhorter and Barrentine (1975) reported that common cocklebur reduced the yield of "Bragg," one of the most competitive cultivars, 7% when grown in 100-cm rows with cultivation and 39% when grown in 33-cm rows without cultivation. The yields of six other cultivars were reduced about 20% in 100-cm rows and 32 to 52% in 33-cm rows. Increasing the soybean seeding rate from 54 to 162 kg/ha increased common cocklebur control with "Lee," "Hill," and "Bragg" cultivars in 33-cm rows.

McWhorter and Hartwig (1972) found that heavy infestations of johnsongrass reduced the yield of six soybean varieties 23 to 42% with both hand-harvesting and mechanical harvesting. "Davis," "Lee," and "Bragg" varieties produced significantly higher yields than did "Semmes," "Jackson," or "Hardee" when grown in weed-free plots, but "Bragg" produced significantly higher yields than all other varieties when grown with johnsongrass. Less regrowth of johnsongrass occurred in plots of "Bragg," "Davis," and "Semmes" than in plots of

"Lee," "Jackson," and "Hardee." Common cocklebur reduced the average yields of six soybean varieties 63 to 75% when plots were hand-harvested. "Semmes" showed the lowest percentage yield reduction from common cocklebur competition when hand-harvested and "Semmes" and "Bragg" showed 53 to 57% reduction, respectively, when machine harvested. "Lee," the shortest variety and one of the earliest in maturity, suffered 41% yield reduction; "Hardee," the latest-maturing variety, had an average 25% yield reduction.

Planting patterns

Weber and Staniforth (1957) determined that soybean stands below 9 to 11 plants per 0.3 m of rows 1 m apart were of considerable importance in increasing severity of yield loss from weeds. Soybeans at three plants per 0.3 m of row were about 7.5 cm shorter and lodged slightly less than beans with 9 or 15 plants per 0.3m. Seed weight of beans decreased 0.2 g per 100 seeds and stands increased from three to 9 to 15 plants per 0.3 m.

Staniforth (1962) reported that soybean stands of 13 to 15 plants per 0.3 m of row (1 m apart) suppressed weed growth and suffered less yield reduction than soybeans in stands of seven to nine plants per 0.3 m.

Hammerton (1972) found in competition studies with mixed weed stands that soybean in narrow rows (30 cm) gave higher yields than in wide rows (60 cm).

Burnside and Colville (1964a) concluded that wide row spacings reduced the height of the lowest pod on soybeans. Narrow row

spacings increased soybean yields and plant population; and decreased weed yields, number of pods per plant, number of seeds per plant, and germination percentage.

Burnside and Colville (1964b) found some advantages of growing soybeans with chloramben applications in 25-cm rows as compared to 100-cm rows: (1) an average soybean yield increase of 39%, (2) elimination or reduction of tillage, (3) a 50 to 75% reduction in herbicide chloramben application rate, and (4) little or no soybean injury from the lower rates of chloramben required in the 50-cm rows. Soybeans in the 25-, 50-, 75-, and 100-cm rows completely shaded the ground between rows in 36, 47, 58, and 67 days, respectively. Comparing yields in narrow rows with soybean yields in 100-cm rows, one finds an average yield increase of 5% in 75-cm rows, 17% in 50-cm rows, and 39% in 25-cm rows.

Kust and Smith (1969) obtained increased soybean yields and weed control as row spacing decreased. Lower rates of linuron were required for comparable weed control as row spacing decreased. Soybeans planted in narrow rows were much more effective than those planted in wide rows in suppressing the growth of yellow foxtail, Setaria glauca (L.) Beauv., and barnyardgrass, Echinochloa crusgalli (L.) Beauv. A decrease of 34, 27, and 20 kg/ha in soybean yield was obtained for every 110 kg/ha increase in weed dry weight for the 35, 70, and 88-cm row spacing.

Peters et al. (1965) discovered that when herbicides were used, soybeans in 50- and 60-cm rows usually needed no more than one cultivation, while those in 80- and 100-cm rows usually needed at least one and sometimes two cultivations for good weed control and high

soybean yields. They also concluded that soybeans grown in narrow rows often out-yielded soybeans grown in wide rows.

Wax and Pendleton (1968) determined that soybean yield increased and weed yield decreased as row spacing was decreased. Compared to the yield from 100-cm rows, soybean yield increase was 10, 18, and 20% for 75-, 50-, and 25-cm rows, respectively. Two varieties formed a canopy in about 35 to 40, 50 to 55, 65 to 70, and 80 to 85 days after planting in 25-, 50-, 75-, and 100-cm rows, respectively.

McWhorter and Barrentine (1975) concluded that common cocklebur was controlled better in soybeans planted in 100-cm rows and grown with cultivation than in those planted in 18- or 33-cm rows and grown without cultivation. Increased soybean yields and better common cocklebur control were obtained when soybean populations were increased from 80,000 to 350,000 plants/ha. But, regardless of row spacing and cultivation, no significant yield increase was obtained from soybean plant populations greater than 140,000 plants/ha.

Burnside (1972) determined that soybean populations did not correlate with weed populations or soybean yields averaged over the 4-year period, indicating that soybeans have the ability to compensate for populations variations.

Lovely and Staniforth (1968) emphasized that agronomic research shows that maximum soybean yields could be obtained with row widths of 20 or 25 cm. They developed a soybean production technique that would allow tractor traffic and provide for narrow rows. They stress that row spacings must be arranged in a manner that will make it possible to remove with a cultivator all but four rows spaced at 75 cm or all but four pairs of rows spaced at 75 cm. The multiple row-spacing

system provides flexibility so that in case of herbicide failure weed control can be obtained by mechanical cultivation. With these cultivations, all rows except single or pairs of rows on 75-cm spacing can be removed.

Hauser et al. (1975) developed for peanuts a row width pattern of four close-rows on tractor wheel centers of 160 cm that may provide complete shade 2 to 4 weeks sooner than rows evenly spaced 80 cm apart. Therefore, if sicklepod is eliminated by herbicides or cultivations for the first 4 weeks and vigorous crop growth is maintained, no applications of herbicides later in the season will be needed.

Cropping systems

Robinson and Dunham (1954) established that soybeans planted with a grain drill in non-cultivated rows 15 cm apart and with winter wheat or winter rye as companion crops yielded as much or more than soybeans without companion crops whether in non-cultivated rows 15 cm apart or in cultivated rows 100 cm apart. Weed control with companion crops was much superior to no companion crop in non-cultivated soybeans, and was about equal to that achieved by cultivation. Establishment of the companion crop in the spring in advance of soybean planting was not as successful as sowing soybeans and companion crop at the same time. In non-cultivated soybeans, wheat, rye, or peas gave excellent although not complete weed control, whereas other companion crops were ineffective. In the cultivated soybeans, none of the companion crops except wheat or rye had much effect on the few weeds present.

Soybean Plant Population and
Row Spacing Relations

Cultivars

Johnson and Harris (1967) investigated the effects of plant populations on soybean yield and characteristics of varieties of different maturity. The 6.5 plants per meter of row produced maximum yields of "Bragg"; all other varieties required 26 plants per meter. Significant response to a population greater than 6.5 plants per meter of row (90 cm apart) did not occur with "Bragg." Yield of neither variety was significantly reduced by the 52 plants per meter of row population. Plant height increased as populations increased through 26 plants per meter of row for all varieties except "Hardee," which required only 13 plants.

Hicks et al. (1969) compared four plant types--short determinate, tall determinate, narrow leaflet, and normal--in various planting patterns. They determined that row spacing and seeding rate did not statistically affect seed yield. The tall determinate types yielded 4.6% more than the normal types. There was no difference in yield between the short determinate and normal or the narrow leaflet and normal plant types. A greater leaf area index (LAI) was provided earlier in the season when plants were spaced in 25-cm rows. LAI increased as seeding rate increased. More light penetrated farther into the canopies of the narrow leaflet type than the normal type.

Planting Date

Caviness and Johnson (1972) showed that 90-cm rows resulted in as high soybean yields as narrow 15-cm rows when a recommended variety was planted before about June 10. However, yields were dramatically increased by use of 15-cm rows when planting was delayed after June 20. When plantings were before June 10, in the 15-cm rows plant lodging and drought stress usually were more severe with high plant populations and yields were reduced.

Smith (1968) reported that all varieties studied produced yields of 2700 kg/ha or more on their optimum planting dates. Optimum planting dates extended over a longer period for varieties with medium and late maturity than for varieties with early and medium early maturing dates. Medium and late maturing varieties produced higher yields at both extremes of the planting dates of this experiment than early and medium-early soybeans. Three-year averages for May 15 and June 15 plantings indicate that Hood and Bragg varieties produce highest yields at row widths of 15- and 30-cm. Average yields of beans planted July 15 do not show any yield trend regardless of row width but yields are considerably less than for May 15 and June 15 plantings. The data indicated that favorable dates of planting vary with variety. No appreciable decrease in yield for Bragg variety occurred until after June 15. Data suggest that only medium and late maturing varieties should be planted on very early and very late dates, or from May 15 to not later than June 15 for early and medium early varieties.

Environmental Factors

Radiant energy

Shaw and Weber (1967) reported that the largest part of light interception by soybeans occurred in the outer 15 to 30 cm of the plant canopy. And, the effect of shading of adjacent rows was greater in 1-m row spacing than in 1.5-m row spacing.

Singh et al. (1968) measured net and spectral radiation profiles for two soybean varieties of different leaf shapes. Net radiation attenuation differences were found for varieties but not for row spacings. The attenuation coefficient for both spectral and net radiation was very high, indicating the principal use of radiation is in the outer periphery of the soybean canopy.

Shibles and Weber (1965) determined that percent solar radiation interception and rate of dry matter production in soybeans increased with increasing leaf area development. Percent interception of solar radiation increased with leaf area development of the communities and approached a maximum asymptotically. Since leaf area index was a function of population development, the communities differed in time of reaching maximum. It required 58, 60, and 71 days from emergence for 130,000, 77,000, and 43,000 plants/ha to reach 95% interception.

Shibles and Weber (1966) studied solar radiation interception and dry matter production in soybeans grown in various planting patterns. Increased population resulted in increased leaf area index and a reduction in the number of days from emergence to 95% solar radiation interception. Dry matter production was a function of

percent solar radiation interception regardless of planting pattern.

Water

Doss and Thurlow (1974) determined the effects of soil water regimes, row widths, and plant populations on water use, rate of plant growth, and yield of soybean varieties. They found that water use rates by soybeans were influenced more by soil water regime than by row width or variety. Average bean yields were influenced more by irrigation or variety than by row width or plant population. Row width and plant population showed little influence on average bean yields. For a period early in the season when plants were 25 to 60 cm high more water was used on 90-cm than on 60-cm rows.

Peters and Johnson (1960) concluded from their studies that soybeans in 100-cm rows do not make full use of the available moisture stored in the soil. They indicated that the greatest benefit from 50-cm rows occurred in the uncovered plots, and may be partly due to reduction of evaporative moisture loss by the more complete shading of the soil under 50-cm rows.

Timmons et al. (1967) discovered that neither row spacing nor plant population significantly affected evapo-transpiration of soybeans. Generally, highest water-use efficiencies were obtained for the lower plant population in 20-cm rows. Yields increased as population and row spacing decreased.

Mannering and Johnson (1969) measured infiltration and soil loss in soybeans at various row spacings. Narrow row spacings (18 and 50 cm) for soybeans significantly increased ground cover as early as 3 to 4 weeks after planting. During the last half of the growing

season infiltration was 24% greater and soil loss 35% less from narrow rows (50 cm) than from wide rows (100 cm).

Nutrients

Fink et al. (1974) studied the combined effects of fertilizer and plant population on the yield of soybeans. They found no significant yield differences among plant populations ranging from 100,000 to 400,000 plants/ha. The 38-cm row spacing yielded significantly more than the 76-cm row spacing at the 400,000 plant population where fertilizer was applied, but row spacing had no effect on yield of unfertilized soybeans. They concluded that plant populations as low as 100,000 plants/ha can produce yields equal to those produced by a higher population under both fertilized and unfertilized conditions.

Buttery (1969a, 1969b) reported that high soybean density (32 plants/m²) reduced the proportion of flowers forming mature pods, while fertilizer application increased it. There was no interaction between fertilizer level and density of planting on any plant characteristic. Fertilizer increased final plant weight mainly by delaying the fall in net assimilation rate and crop growth rate. Leaf area index was increased slightly by fertilizer application. Most of the effects of plant population on growth were attributed to a rise in leaf area index.

Plant Growth and Development

Seed yields

Wiggans (1939) showed that soybean yield decreases with increasing distance between rows. And, that a wide range in the distance between plants in the row has little effect on the production. The soybean plant has the ability to make wide adjustments of space. He concluded that the spacing within the rows giving the maximum yield varies with the width of row (from 7.5 cm apart in the 20-cm rows to 2.5 cm in the 80-cm rows).

Probst (1945) obtained the highest soybean yield when the plants were spaced 5.0 or 7.5 cm apart in rows 75 cm apart.

Lehman and Lambert (1960) studied the effect of spacing on the yield of soybeans. The data indicated that planting at the 50-cm spacing between rows would tend to result in higher yields than planting at the 100-cm spacing. The results obtained for the spacings within rows were variable.

Thompson and Robertson (1969) concluded that soybean generally yielded best at 5.0 to 7.5 cm spacings in the row when row widths were 45 to 68 cm. When rows were 90 cm apart highest yields were obtained for 2.5 to 5.0 cm spacings in the row. They stressed that apparently plant population rather than row width or spacing in the row is the important criterion for soybean yields.

Donovan et al. (1963) reported that the combination of narrowest row and widest plant spacing within the row (17.5 x 7.5 cm) gave the highest yield.

Weber et al. (1966) found that highest seed yields occurred in 25-cm rows with 260,000 plants/ha, while dry matter was maximized in 12.5-cm rows with 520,000 plants/ha. The decrease in yield and the increase in dry weight at higher plant densities suggests that greater plant competition occurred in these treatments.

Basnet et al. (1974) obtained that highest yield resulted from the lower plant density in narrow rows in one year and from higher plant density in wider rows in another year. Yields, therefore, increased as within-row spacing increased in narrow rows and when within-row spacing decreased in wider rows.

Hartwig (1957) emphasized that results of most of the studies about rate of planting and row width in the south indicate that the optimum rate within the row is 10-12 viable seeds per 0.3 m and that there is no yield advantage for planting in rows narrower than 90 to 100 cm. In the north central area plantings show a yield advantage for narrow rows.

Caviness and Johnson (1972) found no advantage in drilling soybeans in 15-cm rows if planting was at a recommended date. Yields appeared to be reduced by high rates of planting in narrow rows at the recommended date of planting.

Smith (1968) reported 3 years' data in Florida from row spacings of 105, 90, 75, 60, 45, 30, and 15 cm row width that indicate that highest yields were obtained with 30 and 15 cm row widths at the May 15 and June 15 plantings.

Yield components

Probst (1945) found little effect of spacing on seed size. Lehman and Lambert (1960) reported that the components, weight per 100 seeds,

and seeds per pod were not substantially affected by changes in spacing and in some cases not at all affected. The components, seeds per plant and pods per plant, on the contrary, changed materially as spacing was changed. Seeds per plant and pods per plant increased markedly as spacing was increased.

Weber et al. (1966) determined that plants produced at highest densities set fewer pods and seeds than those plants at lower densities. Plant spacing and population had a small effect on protein and oil content. Pod numbers per plant and seeds per plant were maximized at the 25-cm row width and consistently decreased with increasing plant population. Seed size was independent of row width and seeds per pod averaged greatest in the 50-cm rows.

Basnet et al. (1974) confirmed that spacings between or within rows affected neither seed weight nor quality. Number of pods on branches, pods on main stem, total pods, and total seeds on a plant basis, in general, increased with the decrease in plant densities per unit area.

Donovan et al. (1963) measured the highest percent oil from the widest row and the widest plant spacing (87.5 x 7.5 cm). Protein showed less response to spacing but was highest at the closest spacing. Iodine number did not respond to spacing. The differential response of oil and yield was best reconciled in a 17.5 x 10 cm pattern.

Hinson and Hanson (1962) reported that in four soybean varieties percent protein decreased and percent oil increased as plant spacings increased. There was no evidence that the effects of spacing treatments on percent protein or percent oil were associated with any other character considered. Competition effect on percent oil and percent protein appeared to be associated with the competition effects on yield.

Morphology

Probst (1945) concluded that spacing had little effect on the height of plants. Also, thick planting was conducive to lodging and delayed maturity.

Lehman and Lambert (1960) found that the number of branches increased as spacing was increased. However, the differences were greater at the lower populations than at the higher populations. The relative importance of branches in the production of seeds and pods varied with spacing while changes in spacing had little or no effect on the relative importance of main stems and branches with respect to seed weight and seeds per pod.

Weber et al. (1966) showed that plants produced at higher densities were taller, more sparsely branched, and lodged more. Those plant population-arrangement combinations favoring a rapid attainment of high leaf area index (i.e., high plant populations and narrow row spacings) were those also having the greatest dry weight accumulation. However, there was little relationship between yield and dry weight accumulation, and dry weight was relatively of little value in yield prediction.

Basnet et al. (1974) studied two row widths (45 and 90 cm), and two in-row spacings (3.8 and 6.4 cm) using five soybean cultivars. Plants in 45-cm row width or 3.8 cm within-row spacing were taller, lodged more, and produced fewer nodes and branches. Height to the first pod increased as row width or in-row spacing decreased. Increased plant height with closer spacing within rows was more from elongation of internodes than from increased number of nodes. Number of nodes decreased by

one to two nodes as row-width and within-row spacing was decreased. The number of nodes per plant was associated with plant height.

Hartwig (1957) stressed that planting at rates heavier than 10 to 12 seeds per 0.3 m of row gives better early season weed control, but a greater amount of lodging usually results.

Caviness and Johnson (1972) emphasized from their experiments that lodging usually was more severe at the high populations and plants showed more severe stress during periods of moisture deficiency.

Hinson and Hanson (1962) reported that genotypes which had late flowering dates, increased height, more branches per plant, and more nodes per plant at wide spacings were able to utilize more efficiently the additional space provided by increased spacings. They stressed that although genetic height and node number are important, the major way plants respond to additional space in yield per plant is through the production of additional branches.

Harvesting Efficiency

Hartwig (1957) emphasized that increased lodging from thick plantings or narrow rows increases problems in maintaining proper combine adjustment, and will frequently result in greater harvesting losses.

Nave and Cooper (1974) reported that excessive seeding rate had a more adverse effect on lodging and yield in 18- to 20-cm rows than in 75-cm rows. Total header loss was excessive at both low and high populations. Threshing and separating loss increased as the population and row width were increased. Stubble height was consistently lower in the 20-cm row plots. Shatter loss was greater in the narrowest rows at

the lowest population and stalk loss was greatest in the widest rows at the highest population.

MATERIALS AND METHODS

Competition studies with soybeans and sicklepod were conducted during 1975 at the Agricultural Research and Education Center of the University of Florida in Quincy, Florida.

Two field experiments were established, one on May 22, 1975, on a Ruston loamy fine sand soil, and the other four weeks later, on June 19, 1975, on a Orangeburg loamy fine sand soil. They will be referred to hereinafter as "experiment 1" and "experiment 2," respectively.

Temperature and rainfall data from May 20 through October 16, 1975, divided in monthly periods, are presented in Table 1.

Table 1. Meteorological data during the growing season in 1975, Quincy, Florida

Period	Mean air temperature (C)			Rainfall (mm)
	Max.	Min.	Average	
May 20 - June 18	35.0	18.4	26.8	112
June 19 - July 18	35.6	18.9	27.3	64
July 19 - Aug. 17	36.0	19.6	27.9	194
Aug. 18 - Sep. 16	36.5	19.3	28.1	98
Sep. 17 - Oct. 16	30.3	15.9	22.1	160

A split-plot experimental design was planted in four replications in which four sicklepod densities were the main plots and six soybean row distances were the subplots (Tables 2 and 3). The main plots were arranged in randomized complete blocks. Thus, 24 treatments with four replicates were involved in each experiment. Individual subplots measured 16 m^2 (3.6 m wide and 4.5 m in length).

Table 2. Sicklepod densities, as average number of plants per hectare, Quincy, Florida

Densities	Experiment 1	Experiment 2
Control	No sicklepod	No sicklepod
Low	25,000	36,000
Medium	53,000	68,000
High	77,000	122,000

Table 3. Soybean row spacing treatments, Quincy, Florida

Row distances (cm)	Soybean population (plants/ha)	Season period (months)	Row distances (cm)	Soybean population (plants/ha)	Season period (months)
Constant rows pattern:					
90	130,000	5	---	---	---
60	195,000	5	---	---	---
45	260,000	5	---	---	---
Variable rows pattern:					
30	390,000	1	90	130,000	4
30	390,000	1	60	195,000	4
30	390,000	1	30-60	260,000	4

Normal fertilization and land preparation for soybean culture were used. "Bragg" soybeans, a maturity group VII cultivar, well adapted to northwest Florida, was used in both experiments. They were planted on fall-plowed lands which had been in soybeans the previous year. The soil seedbeds were prepared before planting in the conventional manner by plowing and disking. Soybeans were seeded about 4 cm deep with a manual planter. Seeding rates were 40, 60, 80, and 120 kg/ha of soybean seed for the 90, 60, 45, and 30 cm row spacings, respectively.

Soybean stands were estimated 5 weeks after planting by counting the number of plants in 5.5 m of rows in half of the plots, and reached approximately the density of 12 plants per linear meter of row, or about one plant each 8.5 cm of row.

Establishment of the final spacings for the three variable row pattern treatments was performed 5 weeks after soybean planting date, when the plants had five to six trifoliate leaves. In these treatments, soybean was initially seeded in rows 30 cm apart. By harvesting alternately an appropriate number of these rows, the final row spacings of 90, 60, and 30-60 cm were established for the remainder of the season.

Also at that stage, calculated dry matter per area of soybean leaves and stems was obtained by oven-drying at 65 C a sample taken from two rows of 2.75 m in length per plot.

Leaf area index and percentage of ground cover were estimated by the point quadrat method, consisting of a needle which was lowered through the canopy while the number of contacts the needle made with the leaves was recorded (Williams and Joseph, 1970). For the determinations of leaf area and ground cover 12 points in a 6 m² area were staked on each plot.

The data for the two planting date experiments were not combined in the same statistical analysis because the second experiment had to be discontinued 3 months after planting due to a severe attack of velvetbean caterpillars, Anticarsia gemmatilis Hubner, that caused complete defoliation of the soybean plants.

All data on the responses of soybean and sicklepod were subjected to an analysis of variance according to standard procedures and treatment means were compared using Duncan's multiple range test. The 5% level of significance was used for all tests.

Correlation coefficients were computed between the soybean and sicklepod factors studied, and regression analyses were performed where useful.

Estimated linear correlations between all possible pairs of responses for experiments 1 and 2 were carried out, and are presented in Tables 19 and 27, respectively. For the correlation to be declared significantly different from zero at the 5% level, the coefficient (as indicated by one asterisk) must exceed in absolute value 0.201. The critical value at the 1% level (two asterisks) is 0.262. Non-significance is represented by NS in these Tables.

Experiment 1

Before this experiment was established, fertilizers were applied as needed for soybeans according to soil tests (Table 4). Prior to planting, 500 kg/ha of a 0-14-14 commercial fertilizer and 2000 kg/ha of dolomitic limestone were spread and disked into the soil.

The study area was sprayed with trifluralin at 1.0 kg/ha as a pre-plant soil-incorporated treatment before soybeans were planted to help

Table 4. Soil fertility and pH in the area of experiment 1 during the growing season, Quincy, Florida

Soil constituents	Initial analysis	Fertilizers applied	Total content	Final analysis
Phosphorus (ppm)	21.0	15.5	36.5	21.5
Potassium (ppm)	37.5	29.0	66.5	111.0
Calcium (ppm)	353.5	231.0	584.5	452.5
Magnesium (ppm)	133.5	130.0	263.5	187.0
pH	6.0	---	---	6.4

control weeds other than sicklepod. The experiment was conducted in an area where sicklepod was the predominant weed species present.

Sicklepod densities were established by hand thinning the naturally emerging plants 2 to 3 weeks after soybeans were planted. Sicklepod plants were randomly distributed over the area and were allowed to compete with soybeans for the full season.

Later germinating sicklepod and other volunteer weeds were removed by hand pulling during the growing season, thus maintaining the densities of sicklepod at desired levels. Check plots were kept weed-free throughout the growing season.

Final sicklepod densities were determined at the end of the growing season by counting the number of plants in 5 m² per plot.

The following data were recorded from this experiment: (1) sicklepod leaf area index (Sic. LA) and ground cover (Sic. GC) 4 and 6 weeks after soybean planting; (2) soybean leaf area index (Soy. LA) and ground cover (Soy. GC) 4 and 6 weeks after planting; (3) soybean dry matter

produced at 5 weeks; (4) soybean plant characteristics: number of branches per plant, number of nodes per plant, stem height, stem diameter, and internode length; (5) components of soybean seed yield: number of pods per plant, number of seeds per plant, number of seeds per pod, weight of seeds per plant, and weight of 100 seeds (seed size); (6) soybean seed yield; (7) total dry weight of sicklepod plants per area; (8) mean dry weight of individual sicklepod plants; (9) soil contents of P, K, Ca, and Mg at harvesting; and (10) soybean seed germination and seedling vigor 1 month after harvesting.

Soybean plant characteristics and components of seed yield were determined from a 10-plant sample taken prior to harvesting (5 months after planting). Therefore, data being reported refer to the averages of these variables on 10 plants.

Numbers of branches and nodes on the main stem were counted, along with measurement of stem height and stem diameter at the second internode. Average internode length was obtained by dividing the mean stem height by the mean number of nodes.

Numbers of pods and seeds per plant were obtained by countings, and weight of seeds per plant was determined by weighing. Number of seeds per pod was evaluated by dividing the mean number of seeds by the mean number of pods. Seed size was calculated from the number of seeds per plant and mean weight of seeds per plant and then being reported as weight of 100 seeds.

Final soybean seed yield data were taken from 5 m^2 (1.8 m wide by 2.8 m in length) in each plot. Soybeans were harvested by hand on October 20, 1975. The plants were pulled and threshed with a stationary plot thresher. The data for seed yield were obtained by adding the

weight of the seeds obtained from the 10-plant sample to the weight of the seeds from the remainder of the plot. Yields are reported for soybeans with 13% moisture.

At soybean maturity, sicklepod was removed from a 5 m² area per plot by hand pulling, and fresh weight was determined by weighing the whole plants. Sicklepod dry weight was obtained through a sample from the weeds harvested in the 5 m² area, dried to constant weight at 65 C in a forced-air drier, and then expressed in kg/ha.

Average weight of individual sicklepod plants was determined by dividing the total dry weight of sicklepod by the number of weeds contained in the same area at that time.

At the end of the season, soil contents of phosphorus, potassium, calcium, and magnesium were determined by the Soil Analysis Laboratory of the Agricultural Research and Education Center in Quincy. Soil samples consisted of five sub-samples taken from the 5 m² harvested area of each plot.

One month after harvesting, soybean seed germination and seedling vigor were tested in greenhouse trials. Using four replicates per each of the field treatments, 20 soybean seeds were planted in plastic pots containing field soil. Ten days after planting, percent germination was recorded by counting the number of seedlings emerged, and seedling vigor was estimated by taking the fresh weight of the shoots.

Estimated regression equations were based on the data from experiment 1. Four models were fitted to the experimental data. These were (1) a quadratic equation in a single independent variable using the original (arithmetic) scale, (2) a linear equation in a single independent variable using a logarithmic transformation of the dependent variable, (3) a quadratic equation in a single independent variable

using the reciprocal of the dependent variable, and (4) a linear equation in a single independent variable using a logarithmic transformation of both the independent and dependent variables. Models (3) and (4) will be referred to as the reciprocal and log-log models, respectively.

To estimate the equations based on the original scale, the following procedure was used. The linear equation was first fitted to the data. If a significant regression was obtained (that is, if the linear coefficient was significantly different from zero), the quadratic component was added to the model. If the addition of the quadratic term significantly improved the fit of the equation, then the relationship was taken to be quadratic; otherwise, the linear equation is reported. The procedure used to estimate the regression equations for the reciprocal model is the same as described above.

A significance level of 5% was used to determine improvement in fit. In fitting the logarithmic model, natural logarithms were used.

When the responses were related to sicklepod that had no sicklepod plants under the control, it was decided to force the relationship through zero and use only the information from the low, medium, and high densities in fitting the quadratic model. Again, when fitting the reciprocal and logarithmic models and the responses were associated with sicklepod, it was necessary to omit the data for the control because of the existence of zeros since neither transformation is defined for a value of zero.

Regression equations between final soybean populations (resultant from the combination of row spacings) and certain responses were also estimated for experiment 1. The purpose of this analysis was twofold: (1) to determine if a regression relationship exists between final

population and each response, and (2) if there is a relationship, determine if it is independent of initial soybean population and/or sicklepod density. Separate equations were estimated for sicklepod densities, since the regression relationships with final soybean populations were not the same for each sicklepod density.

For experiment 1 a multiple regression equation was obtained relating soybean seed yield with the independent variables of yield components. The model was taken to be linear in all independent variables. The actual regression equation was estimated using a step-wise procedure. Under this procedure, no independent variable was included in the final equation unless its contribution to the relationship was significant. Significance was defined as rejection of the null hypothesis of no relationship at the 10% level.

An analysis based on data from experiment 1 was performed to determine if a difference existed between "expected" and "observed" soybean seed yields. The hypothesis of no difference was tested using the paired t-test. "Observed" soybean seed yield was defined as the seed yield actually obtained from the plants harvested from 5 m² per plot; while "expected" soybean seed yield was the yield calculated by using the variables number of seeds per plant, average seed size, and number of soybean plants per area.

Experiment 2

In this experiment, sicklepod was planted by hand on a sicklepod-free area. Sicklepod seeds were not scarified to more closely simulate natural conditions, and broadcast by hand one day before soybeans were planted.

Volunteer weeds were removed by hand pulling and check plots kept weed-free throughout the growing period. The sicklepod densities were allowed to compete for the full season with soybeans.

Sicklepod stands were evaluated 1 month after planting by counting the number of plants in an area of 8 m^2 on each individual plot.

Data recorded from this experiment included (1) sicklepod ground cover (Sic. GC) and leaf area index (Sic. LA) 4, 5, and 7 weeks after soybean planting; (2) soybean ground cover (Soy. GC) and leaf area index (Soy. LA) 4, 5, and 7 weeks after planting; (3) soybean dry matter produced at 5 weeks; (4) soybean plant characteristics: number of branches per plant, number of nodes per plant, number of leaves per plant, and stem height; and (5) number of pods per soybean plant at 3 months after planting.

Soybean plant characters and number of pods were estimated from a 10-plant sample taken 3 months after planting, on September 18, 1975, when the experiment was interrupted due to severe insect damage. Variables to be reported represent the averages on these 10 plants. Numbers of branches, nodes, leaves, and pods per plant were determined by countings, and stem height was measured.

RESULTS

Experiment 1

Twenty-eight responses were measured in experiment 1. Results of the analyses of variance are summarized in the Appendix Table A-1. In this table only mean squares have been provided. Significant effects have been indicated by asterisks after the appropriate mean squares.

From the results of the analyses of variance, it will be observed that 16 responses had significant differences among sickleped densities and 18 responses were significantly affected by row distances. There were six responses which were unaffected by either experimental factor, while 12 showed significant differences due to both. Of these latter responses, five had significant density x row distance interactions.

Main effect means associated with these analyses and results of Duncan's test performed on the density and row distance means are presented in Tables 5, 9, 10, 13, and 18. For five responses the interaction between density and row distance was found to be statistically significant. The nature of these interactions are examined in Tables 6, 7, 11, 12, and 16. Presented in these tables are the interaction means and the results of Duncan's test on the means of one factor for all levels of the second.

Estimated linear correlations between all possible pairs of responses are presented in Table 19.

Contained in Tables 14 and 15 are the estimated regression equations for the arithmetic, logarithmic, reciprocal, and log-log models, respectively. Independent variables considered were sicklepod density and dry weight per area, while the dependent variables were numbers of pods and seeds per soybean plant, seeds per pod, and seed yields per plant and per area. In addition to providing the estimated regression equations in these tables, the coefficient of determination (R^2) is also given.

Four other equations, presented in Table 8, were estimated using sicklepod dry weight per area and per plant as the dependent variable and sicklepod density as the independent variable. These equations were associated with the arithmetic, logarithmic, reciprocal, and log-log models.

Appendix Table A-2 presents the breakdown of the row and row x density sum of squares according to the factorial structure of the treatments for eight responses (sicklepod dry weight per area and per plant, numbers of soybean pods and seeds per plant, seeds per pod, weight of 100 seeds, and seed yields per area and per plant). The six row distances (factor B) in the experiment formed a 2 x 3 factorial in initial and final soybean populations.

Results of the analysis indicated that the final population did affect some variables. For the number of soybean pods and seeds per plant, weight of seeds per plant, and sicklepod dry weight per plant, the interaction between final soybean population and sicklepod density was found to be significant. Separate equations for the sicklepod densities have been estimated and are presented in Table 17. For soybean

seed yield per area, the effect of final population was independent of both initial population and sicklepod density.

Sicklepod

Ground cover and leaf area index

Percentage of ground cover and leaf area index of sicklepod plants, determined 4 weeks after soybean planting date, were highest for the high sicklepod density (Table 5, Figure 1). However, at this stage no differences were found concerning the low and medium densities. Four weeks after establishment no effects of the various soybean row distances in relation to ground cover and leaf area of sicklepod plants were detected.

Ground cover and leaf area of sicklepod at 6 weeks increased with increasing densities of the weed, although the low and medium densities still were statistically similar when leaf area index is considered. At 6 weeks, soybeans in 90-cm row width since the beginning permitted more growth of sicklepod (ground cover and leaf area) than any other row spacing treatment, except for soybeans constantly in 60-cm rows.

The growth rate of sicklepod, as measured by these parameters, was very rapid from 4 to 6 weeks. On the average, ground cover more than doubled during this period, as compared with the first 4 weeks, and leaf area index increased three times.

Dry weight

Per area. Sicklepod dry weight per area for the low weed density was significantly higher in soybeans planted in 60-cm rows throughout

Table 5. Sicklepod ground cover, leaf area index, and dry weight as influenced by sicklepod densities and soybean row distances in experiment 1

Factors	Sicklepod ^a				
	Percentage ground cover ^b		Leaf area index ^b		Dry weight ^c
	4 weeks	6 weeks	4 weeks	6 weeks	
Sicklepod/ha: ^d					kg/ha g/plant
None	0.00 ^c	0.00 ^d	0.000 ^c	0.000 ^c	0 0.0
25,000	6.25 ^b	11.11 ^c	0.073 ^b	0.153 ^b	3723 147.1
53,000	6.60 ^b	21.18 ^b	0.069 ^b	0.274 ^b	5383 104.2
77,000	13.89 ^a	32.29 ^a	0.167 ^a	0.507 ^a	5535 77.9
Row distances: ^e					
90 cm	7.29 ^e	23.96 ^e	0.083 ^e	0.349 ^e	4324 83.9
60 cm	5.73 ^e	17.71 ^{ef}	0.062 ^e	0.271 ^{ef}	3762 79.5
45 cm	5.21 ^e	16.15 ^f	0.073 ^e	0.224 ^{fg}	3540 74.5
30 to 90 cm	9.38 ^e	16.14 ^f	0.094 ^e	0.208 ^{fg}	3751 87.4
30 to 60 cm	5.73 ^e	10.42 ^f	0.073 ^e	0.151 ^g	3536 87.4
30 to 30-60 cm	6.77 ^e	12.50 ^f	0.078 ^e	0.198 ^{fg}	3049 81.1
Overall means	6.68	16.15	0.077	0.234	3660 82.3

^a Means within columns followed by the same letter do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

^b Time after soybean planting date.

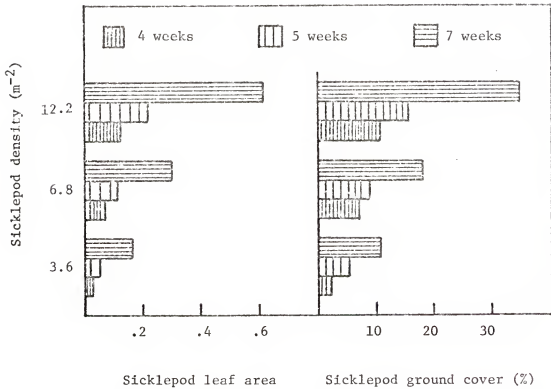
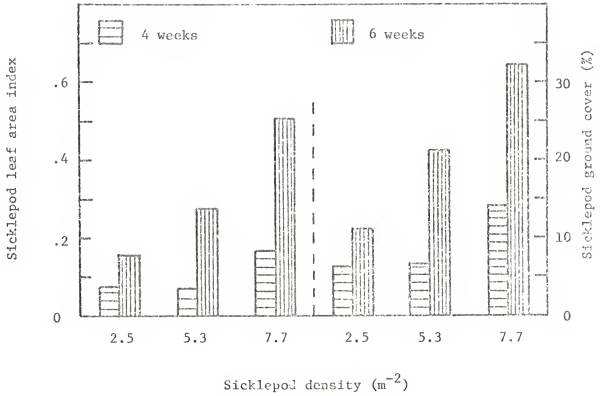
^c Interaction sicklepod densities x soybean row distances present.

^d Values are average of four replications, across soybean row distances.

^e Values are average of four replications, across sicklepod densities.

Figure 1. Sicklepod leaf area index and ground cover as affected by the weed density at two times during the growing season, in experiment 1

Figure 2. Sicklepod leaf area index and percentage of ground cover as influenced by the weed density at three times during the growing season, in experiment 2.



the season than for soybeans in 45-cm rows (Table 6). For the medium sicklepod density, dry weight per area was highest in soybeans cultivated in 90-cm rows throughout the season. When the rows were changed during the season there was significantly more sicklepod growth (dry weight) with rows spaced 90 cm than in rows 30-60 cm apart.

At high weed densities, soybean row width did not significantly influence sicklepod dry weight (Table 6).

Table 6. Effect of sicklepod densities and soybean row distances on sicklepod dry weight per area (kg/ha) in experiment 1^{ab}

Soybean row distances	Sicklepod densities (per ha)			
	None	25,000	53,000	77,000
90 cm	c ₀ ^e	b ₄₃₉₈ ^{ef}	a ₇₆₆₇ ^e	b ₅₂₃₀ ^e
60 cm	b ₀ ^e	a ₄₆₅₆ ^e	a ₄₆₅₂ ^{fg}	a ₅₇₄₁ ^e
45 cm	d ₀ ^e	c ₂₈₈₂ ^f	b ₄₈₇₇ ^{fg}	a ₆₄₀₁ ^e
30 to 90 cm	c ₀ ^e	b ₃₇₁₄ ^{ef}	a ₆₁₆₂ ^f	ab ₅₁₃₀ ^e
30 to 60 cm	c ₀ ^e	b ₃₅₁₂ ^{ef}	a ₅₀₉₁ ^{fg}	a ₅₅₄₂ ^e
30 to 30-60 cm	c ₀ ^e	b ₃₁₈₀ ^{ef}	ab ₃₈₄₈ ^g	a ₅₁₆₆ ^e

^a Means within a row preceeded by the same letter, or means within a column followed by the same letter are not significantly different at the 5% probability level, as determined by Duncan's multiple range test.

^b Values are average of four replications.

Sicklepod dry weight per area tended to increase from the low to the medium density, but not so much from the medium to the high weed density (Tables 5 and 6).

Considering the various row spacings, there was a general trend for greater sicklepod dry weight production in rows 90 cm apart than in the closer spacings of 45 and 30-60 cm under low and medium weed densities. Also, constant row widths throughout the season tended to produce more sicklepod dry weight than the variable rows.

Per plant. At constant soybean rows throughout the season, dry weight of individual sicklepod plants, at the low weed density, was significantly lower in rows spaced at 45 cm as compared to rows 90 and 60 cm apart. However, for the medium weed density dry weight per sicklepod plant was significantly lower in soybeans planted at 60 cm in comparison with the 90-cm rows (Table 7). For the high sicklepod density, the size (dry weight) of the plants remained the same, regardless of row distances in the constant pattern.

Table 7. Effect of sicklepod densities and soybean row distances on sicklepod dry weight per plant (g) in experiment 1^{ab}

Soybean row distances	Sicklepod densities (per ha)			
	None	25,000	53,000	77,000
90 cm	d ₀ ^e	a _{150.9} ^e	b _{121.4} ^e	c _{63.3} ^f
60 cm	c ₀ ^e	a _{169.5} ^e	b _{76.8} ^f	b _{71.7} ^{ef}
45 cm	c ₀ ^e	a _{116.9} ^f	ab _{95.2} ^{ef}	b _{85.8} ^{ef}
30 to 90 cm	d ₀ ^e	a _{157.0} ^e	b _{121.6} ^e	c _{71.0} ^{ef}
30 to 60 cm	c ₀ ^e	a _{144.4} ^{ef}	b _{108.4} ^e	b _{97.0} ^e
30 to 30-60 cm	c ₀ ^e	a _{144.1} ^{ef}	b _{101.6} ^{ef}	b _{78.9} ^{ef}

^aMeans within a row preceeded by the same letter, or means within a column followed by the same letter are not significantly different at the 5% probability level, as determined by Duncan's multiple range test.

^bValues are average of four replications.

Soybeans planted in variable row spacings during the season did not significantly affect the dry weight of individual sicklepod plants (Table 7).

Generally there was a trend for dry weight per sicklepod plant to decrease as the weed density increased (Tables 5 and 7). Between weed density levels the differences in size of sicklepod plants were greatest in soybean rows 90 cm apart, at either constant or variable row spacings. The decreases of sicklepod dry weight per plant with increases in the weed density were smaller for the other soybean row treatments, and the differences were especially undetectable when comparing the medium with the high weed density.

From the regression equations of Table 8, Figures 3 and 4 show the increase in sicklepod dry weight per area and the decrease in dry weight per plant as the weed density increased. The influence of row distances (or soybean populations) on dry weight of sicklepod plants under the low weed density is seen in Figure 24.

Soybean

Ground cover and leaf area index

Until 6 weeks after soybean planting there were no significant effects of sicklepod densities on soybean ground cover and on leaf area index (Table 9).

At 4 weeks, percentage ground cover and leaf area index were highest for soybeans in 30-cm rows, and these variables decreased progressively with increases in row distances (Table 9, Figures 5 and 6).

Table 8. Estimated regression equations for sicklepod dry weight as dependent on sicklepod density (plants/10 m²) in experiment 1

Variables	Models ^{ab}	Regression equations ^{cd}	R ²
Dry weight per area	Arithmetic	$151.0393X - 0.8337X^2$	---
	Logarithmic	$7.9891 + 0.008262X$	0.298
	Reciprocal	$0.0^34829 - 0.0^57435X + 0.0^7422X^2$	0.371
	Log-log	$6.6173 + 0.4727X$	0.390
Dry weight per plant	Arithmetic	$4.4457X - 0.03844X^2$	---
	Logarithmic	$5.1799 - 0.01101X$	0.484
	Reciprocal	$0.004391 + 0.0^31262X$	0.486
	Log-log	$6.6171 - 0.5272X$	0.443

^a Arithmetic: $Y = bX + cX^2$ Logarithmic: $\log Y = a + bX$ Reciprocal: $1/Y = a + bX$ or $1/Y = a + bX + cX^2$ Log-log: $\log Y = a + b \log X$ ^b Natural logarithms were used in fitting the logarithmic models.^c Significant at the 5% probability level.^d 0.0³4829 is read 0.0004829.

At 6 weeks, as a result of establishment of the final row widths for the variable row pattern, ground cover and leaf area of these particular treatments generally decreased in comparison with the previous values attained at 4 weeks. However, the values were equivalent for the same row spacings, either in the constant or the variable system, except for rows 60 cm apart, where ground cover and leaf area were lower for the variable than for the constant pattern. There was a

Figure 3. Influence of sicklepod density on dry weight of sicklepod per area and per plant, presented in reciprocal scales

Figure 4. Sicklepod dry weight per area and per plant as influenced by sicklepod density; variables are presented in logarithmic scales

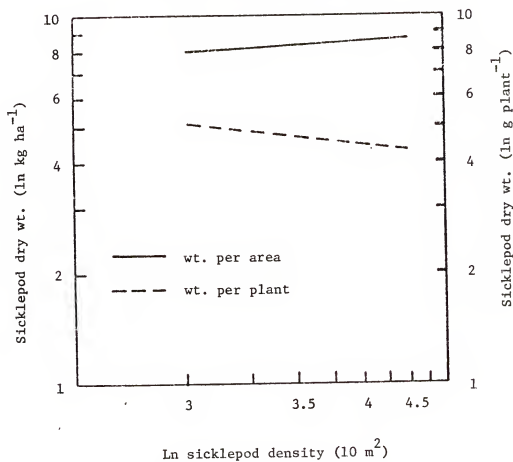
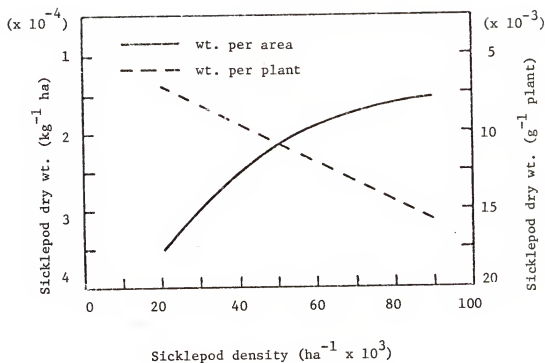


Table 9. Soybean ground cover, leaf area index, and dry matter as influenced by sicklepod densities and soybean row distances in experiment 1

Factors	Soybean ^a				
	Percentage ground cover ^b		Leaf area index ^b		Dry matter ^c kg/ha
	4 weeks	6 weeks	4 weeks	6 weeks	
Sicklepod/ha: ^d					
None	57.29 ^a	66.32 ^a	0.920 ^a	1.264 ^a	293.8 ^a
25,000	56.25 ^a	56.94 ^a	0.934 ^a	1.017 ^a	279.3 ^a
53,000	54.51 ^a	60.07 ^a	0.865 ^a	1.104 ^a	273.7 ^a
77,000	52.43 ^a	56.60 ^a	0.816 ^a	1.035 ^a	217.7 ^a
Row distances: ^e					
90 cm	23.96 ^h	46.87 ^{gh}	0.365 ^h	0.922 ^f	0.0 ^h
60 cm	35.42 ^g	64.58 ^f	0.557 ^g	1.271 ^e	0.0 ^h
45 cm	52.08 ^f	78.65 ^e	0.813 ^f	1.516 ^e	0.0 ^h
30 to 90 cm	72.40 ^e	40.10 ^h	1.198 ^e	0.672 ^f	694.0 ^e
30 to 60 cm	72.40 ^e	55.21 ^g	1.177 ^e	0.875 ^f	540.2 ^f
30 to 30-60 cm	74.48 ^e	74.48 ^e	1.193 ^e	1.375 ^e	362.5 ^g
Overall means	55.12	59.98	0.884	1.105	266.1

^aMeans within columns followed by the same letter do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

^bTime after soybean planting date.

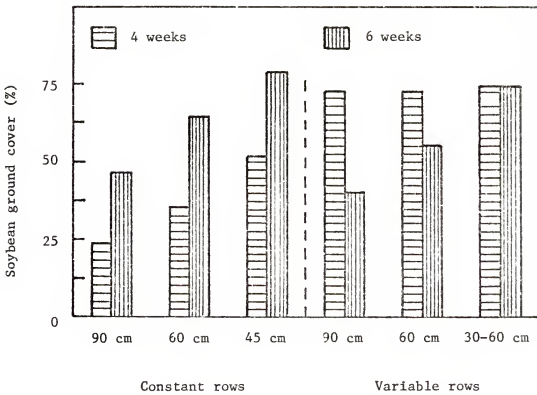
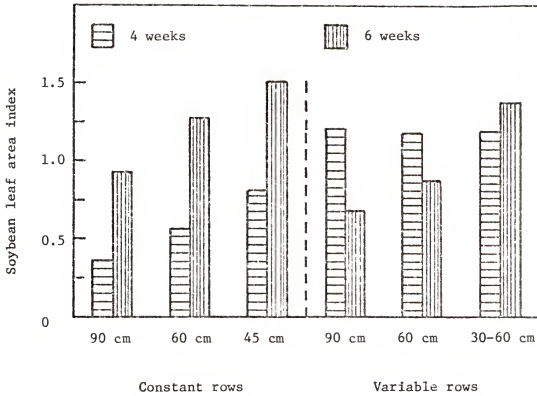
^cAt 5 weeks after soybean planting date.

^dValues are average of four replications, across soybean row distances.

^eValues are average of four replications, across sicklepod densities.

Figure 5. Soybean leaf area index as affected by row distance patterns at two times during the growing season, in experiment 1

Figure 6. Soybean ground cover as affected by row distance patterns at two times during the growing season, in experiment 1



decrease in the values obtained, especially for ground cover, as row width became wider.

Soybean ground cover and leaf area at 4 weeks were not correlated with sicklepod ground cover and leaf area at that same time (Table 19). And, neither were soybean ground cover and leaf area at 6 weeks correlated with sicklepod ground cover and leaf area at 4 weeks. But, sicklepod ground cover and leaf area at 6 weeks were negatively correlated with soybean ground cover and leaf area at 4 weeks.

Soybean ground cover and leaf area at 4 or 6 weeks after planting were only slightly correlated with sicklepod densities. However, sicklepod dry weight per area was negatively correlated with soybean ground cover and leaf area at 6 weeks.

Dry matter

Dry matter of soybeans in the 30-cm row treatments until 5 weeks after planting did not show effects of sicklepod competition (Table 9).

For the variable row system, dry matter of soybeans increased with the number of rows cut to establish the final row distances, with the highest production for 90-cm rows and decreasing with the closer spacings of 60 and 30-60 cm.

Plant characteristics

Branches. The number of branches per soybean plant decreased significantly under the higher weed populations (Table 10, Figure 7).

Number of branches also decreased significantly for plants in the closer row spacings of 45 and 30-60 cm, as compared with soybeans grown in 90-cm rows (Figure 8).

Table 10. Effect of sicklepod densities and soybean row distances on soybean plant characters in experiment 1

Factors	Soybean plant characters ^a				
	Branches (no.)	Nodes (no.)	Stem diameter (mm)	Stem height (cm)	Internode length ^b (cm)
Sicklepod/ha: ^c					
None	7.967 ^a	15.81 ^a	7.190 ^a	87.59 ^a	5.550
25,000	7.188 ^{ab}	15.50 ^{ab}	6.626 ^b	87.75 ^a	5.670
53,000	6.608 ^{bc}	15.07 ^b	6.082 ^c	86.21 ^a	5.715
77,000	6.292 ^c	15.19 ^b	5.952 ^c	87.48 ^a	5.755
Row distances: ^d					
90 cm	7.894 ^e	15.48 ^e	6.798 ^e	84.51 ^f	5.463
60 cm	6.662 ^f	15.67 ^e	6.389 ^{fg}	90.03 ^e	5.742
45 cm	6.062 ^f	15.58 ^e	6.206 ^{fg}	92.66 ^e	5.962
30 to 90 cm	7.675 ^e	15.34 ^e	6.806 ^e	82.22 ^f	5.356
30 to 60 cm	7.575 ^e	15.21 ^e	6.466 ^f	84.09 ^f	5.526
30 to 30-60 cm	6.212 ^f	15.06 ^e	6.109 ^g	90.02 ^e	5.985
Overall means	7.013	15.39	6.462	87.26	5.672

^aMeans within columns followed by the same letter do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

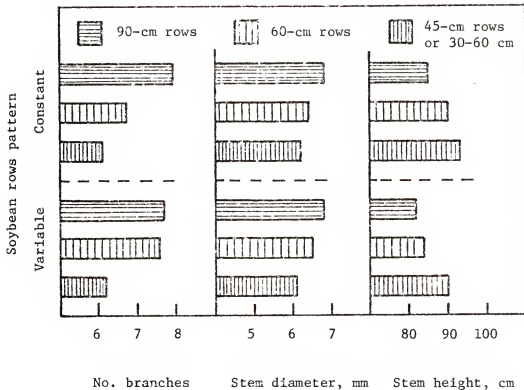
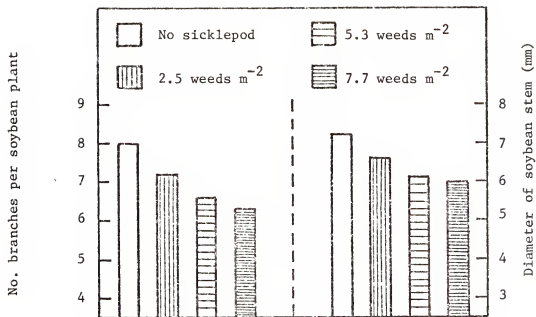
^bInteraction sicklepod densities x soybean row distances present.

^cValues are average of four replications, across soybean row distances.

^dValues are average of four replications, across sicklepod densities.

Figure 7. Number of branches per soybean plant and diameter of soybean stem at harvest, as affected by sicklepod densities, in experiment 1

Figure 8. Number of branches per soybean plant, stem diameter, and height of soybeans at harvest, under various row distance patterns, in experiment 1



Nodes. The number of nodes in soybean stems at the medium and high sicklepod densities was significantly lower than for soybeans in weed-free plots (Table 10). None of the row distance treatments significantly affected the number of nodes of soybeans.

Diameter. Sicklepod densities significantly decreased the stem diameter of soybeans. However, the thickness of soybean stems under medium and high weed densities was similar (Table 10, Figure 7).

Stems of soybean plants grown in row widths of 45 and 30-60 cm were smaller in diameter than those of soybeans in 90-cm rows (Table 10, Figure 8). Soybeans in rows 60 cm apart tended to present intermediate stem diameters.

Height. Sicklepod competition did not significantly affect stem height of soybean plants at any of the densities investigated (Table 10). However, height of soybeans varied with the row distance treatments. Generally, plants were taller in the closer spacings of 45 and 30-60 cm, and shorter at the wider widths of 90 cm (Table 10, Figure 8). Soybeans in constant rows showed a tendency to be taller than those in the variable row pattern.

Internodes. Mean internode length of soybean plants generally increased for the narrow row widths of 45 and 30-60 cm (Tables 10 and 11). The differences were more obvious for the higher sicklepod densities than for the weed-free and low density. Shorter internodes occurred in soybeans at 90-cm row treatments under the low sicklepod density; and longer internodes appeared in soybeans at either 45 or 30-60 cm rows under the high weed density. For 45-cm rows, the average length of soybean internodes was significantly shorter in the weed-free than in the weedy plots.

Table 11. Effect of sicklepod densities and soybean row distances on the average length (cm) of soybean internodes in experiment 1^{ab}

Soybean row distances	Sicklepod densities (per ha)			
	None	25,000	53,000	77,000
90 cm	^a 5.512 ^{fg}	^a 5.268 ^f	^a 5.465 ^{fg}	^a 5.608 ^f
60 cm	^a 5.762 ^{ef}	^a 5.805 ^e	^a 5.822 ^{efg}	^a 5.580 ^f
45 cm	^b 5.465 ^{fg}	^a 5.912 ^e	^a 6.180 ^e	^a 6.290 ^e
30 to 90 cm	^a 5.068 ^g	^a 5.442 ^{ef}	^a 5.502 ^{fg}	^a 5.412 ^f
30 to 60 cm	^a 5.405 ^{fg}	^a 5.832 ^e	^a 5.395 ^g	^a 5.472 ^f
30 to 30-60 cm	^a 6.085 ^e	^a 5.760 ^e	^a 5.928 ^{ef}	^a 6.168 ^e

^a Means within a row preceded by the same letter, or means within a column followed by the same letter are not significantly different at the 5% probability level, as determined by Duncan's multiple range test.

^b Values are average of four replications.

The soybean plant characteristics of stem diameter, followed by number of branches, were the variables most negatively correlated with sicklepod ground cover, leaf area index, density, and dry weight per area (Table 19). Number of nodes was less associated with these sicklepod responses, and stem height was not correlated at all with them.

The soybean parameters were poorly correlated with soybean ground cover and leaf area, except stem height, which was highly correlated with ground cover and leaf area of soybean 6 weeks after planting.

Number of branches with stem diameter were positively correlated; while number of branches and stem height were negatively associated. The number of nodes was positively correlated with stem diameter and height.

Components of yield

Pods. Under weed-free conditions, the number of pods per soybean plant was significantly greater in rows spaced 90 cm than in the other widths (Table 12). The differences among row spacings were smaller for low sicklepod density, and disappeared when compared within medium and high densities (Table 12, Figure 21).

For the various row widths, number of pods significantly decreased from weed-free conditions to low density of sicklepod. Number of pods decreased from low to medium weed density, for soybeans in the 90-cm row treatments and in 30-60-cm rows. But, it remained the same when comparing row distances from medium to high levels (Table 12).

Table 12. Effect of sicklepod densities and soybean row distances on the number of pods per soybean plant in experiment 1^{ab}

Soybean row distances	Sicklepod densities (per ha)			
	None	25,000	53,000	77,000
90 cm	^a 84.05 ^e	^b 41.68 ^f	^c 27.02 ^e	^c 23.58 ^e
60 cm	^a 64.40 ^f	^b 33.08 ^f	^b 28.08 ^e	^b 19.55 ^e
45 cm	^a 58.15 ^f	^b 31.85 ^f	^b 24.78 ^e	^b 18.70 ^e
30 to 90 cm	^a 86.38 ^e	^b 59.48 ^e	^c 27.70 ^e	^c 28.50 ^e
30 to 60 cm	^a 70.02 ^f	^b 42.60 ^f	^b 34.40 ^e	^b 29.25 ^e
30 to 30-60 cm	^a 57.95 ^f	^b 39.92 ^f	^c 26.75 ^e	^c 24.05 ^e

^aMeans within a row preceeded by the same letter, or means within a column followed by the same letter are not significantly different at the 5% probability level, as determined by Duncan's multiple range test.

^bValues are average of four replications.

The number of pods decreased 41, 60, and 66% for the low, medium, and high sicklepod densities, respectively (Figure 9).

The effects of sicklepod density and sicklepod dry matter production on number of soybean pods are graphically shown in Figures 11 and 13, taken from the arithmetic equations presented in Tables 14 and 15. There was a tendency for soybeans cultivated at variable row distances to produce more pods than those of the constant pattern (Figure 10).

Seeds. Number of seeds per soybean plant decreased as the sicklepod density increased (Table 13). However, there was no statistical difference in regard to medium and high weed densities. Number of seeds decreased 44, 64, and 70% for the low, medium, and high sicklepod densities, respectively (Figure 9).

Soybeans in rows 90 cm apart produced significantly greater number of seeds than those at either 45- or 30-60-cm rows (Figure 10). Soybeans in 60-cm row width resulted in intermediate number of seeds per plant.

The influences of sicklepod density and dry weight on number of seeds per soybean plant are shown graphically in Figures 12 and 14, calculated from the arithmetic equations of Tables 14 and 15.

The differences among row widths in regard to number of seeds were greatest for soybeans under weed-free conditions, decreased for low weed infestation, and were insignificant when the medium and high densities are considered (Figure 22).

Seeds per pod. Sicklepod infestations reduced significantly the number of seeds per pod in soybean plants, mainly at the high weed density (Table 13). However, for the various row distance treatments, the number of seeds per pod remained statistically unchanged.

Figure 9. Percent of the maximum numbers of pods and seeds, yields per plant and per area of soybeans at different sicklepod densities, in experiment 1

Figure 10. Percent of the maximum numbers of pods and seeds, yields per plant and per area of soybeans at various row distance patterns, in experiment 1

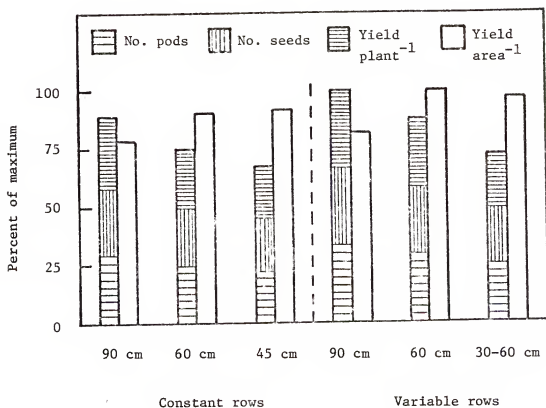
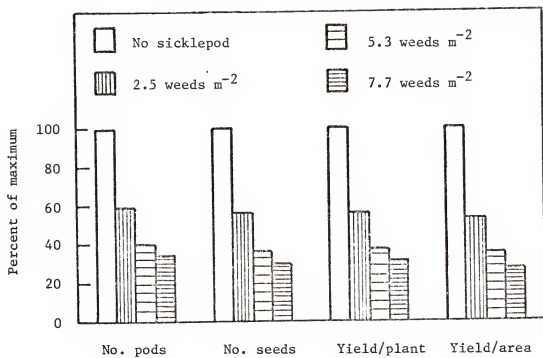


Table 13. Soybean yield and components of yield as influenced by sicklepod densities and soybean row distances in experiment 1^a

Factors	Soybean seed yield (kg/ha)	Pods per plant ^b (no.)	Seeds per plant (no.)	Seeds per pod (no.)	Seed wt. per plant (g)	Wt. per 100 seeds ^b (g)
Sicklepod/ha: ^c						
None	3118 ^a	70.16	125.7 ^a	1.787 ^a	16.22 ^a	12.89
25,000	1651 ^b	41.43	69.9 ^b	1.681 ^b	9.05 ^b	13.03
53,000	1084 ^c	28.12	45.6 ^c	1.615 ^b	6.08 ^c	13.33
77,000	841 ^d	23.94	37.7 ^c	1.540 ^c	5.10 ^c	13.32
Row distances: ^d						
90 cm	1464 ^f	44.08	75.4 ^{ef}	1.633 ^e	10.10 ^{ef}	13.53
60 cm	1674 ^{ef}	36.28	64.6 ^{fg}	1.693 ^e	8.53 ^{efgh}	13.40
45 cm	1707 ^{ef}	33.37	58.08	1.701 ^e	7.53 ^h	13.16
30 to 90 cm	1518 ^f	50.51	84.7 ^e	1.636 ^e	11.02 ^e	13.16
30 to 60 cm	1866 ^e	44.07	74.9 ^{ef}	1.666 ^e	9.64 ^{efg}	12.77
30 to 30-60 cm	1812 ^e	37.17	60.8 ^g	1.608 ^e	7.86 ^{gh}	12.85
Overall means	1674	40.91	69.7	1.656	9.11	13.14

^a Means within columns followed by the same letter do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

^b Interaction sicklepod densities x soybean row distances present.

^c Values are average of four replications, across soybean row distances.

^d Values are average of four replications, across sicklepod densities.

Table 14. Estimated regression equations for the variables soybean yield and components of yield in experiment 1, dependable on sicklepod density (plants/10 m²)

Variables	Models ^a	Regression equations ^{bcd}	R ²
Seed yield	Arithmetic	$2996.1858 - 54.5908X + 0.3111X^2$	0.815
	Logarithmic	$7.8733 - 0.01647X$	0.684
	Reciprocal	$0.0^{32994} + 0.0^{41562}X$	0.440
	Log-log	$9.4257 - 0.6459X$	0.462
No. of pods per plant	Arithmetic	$68.3671 - 1.1254X + 0.006342X^2$	0.732
	Logarithmic	$4.0902 - 0.01314X$	0.682
	Reciprocal	$0.01576 + 0.0^{34142}X$	0.569
	Log-log	$5.3401 - 0.5189X$	0.514
No. of seeds per plant	Arithmetic	$121.7251 - 2.1526X + 0.01233X^2$	0.710
	Logarithmic	$4.6503 - 0.01474X$	0.667
	Reciprocal	$0.008578 + 0.0^{32984}X$	0.503
	Log-log	$6.0426 - 0.5793X$	0.483
No. of seeds per pod	Arithmetic	$1.7573 - 0.002617X$	0.215
	Logarithmic	$0.5601 - 0.001600X$	0.212
	Reciprocal	$0.5733 + 0.06327X$	0.207
	Log-log	$0.7034 - 0.06081X$	0.096
Wt. of seeds per plant	Arithmetic	$15.6638 - 0.2741X + 0.001597X^2$	0.655
	Logarithmic	$2.5890 - 0.01411X$	0.588
	Reciprocal	$0.06535 + 0.002384X$	0.333
	Log-log	$3.8455 - 0.5358X$	0.368

^aArithmetic: $Y = a + bX$ or $Y = a + bX + cX^2$

Logarithmic: $\log Y = a + bX$

Reciprocal: $1/Y = a + bX$

Log-log: $\log Y = a + b \log X$.

^bSignificant at the 5% probability level.

^c0.0³²⁹⁹⁴ is read 0.0002994.

^dNatural logarithms were used in fitting the logarithmic models.

Table 15. Estimated regression equations for the variables soybean yield and components of yield in experiment 1, dependable on sicklepod dry weight (kg/ha)

Variables	Models ^{ab}	Regression equations ^{cd}	R ²
Seed yield	Arithmetic	$3091.0489 - 0.5645X + 0.0^43192X^2$	0.860
	Logarithmic	$8.0288 - 0.0^32169X$	0.784
	Reciprocal	$0.0^31925 + 0.0^61945X$	0.450
	Log-log	$14.6776 - 0.9161X$	0.533
No. of pods per plant	Arithmetic	$69.6530 - 0.01224X + 0.0^67911X^2$	0.705
	Logarithmic	$4.1649 - 0.0^31596X$	0.665
	Reciprocal	$0.01430 + 0.0^54786X$	0.502
	Log-log	$8.1775 - 0.5717X$	0.357
No. of seeds per plant	Arithmetic	$124.3778 - 0.02320X + 0.0^51489X^2$	0.696
	Logarithmic	$4.7437 - 0.0^31816X$	0.669
	Reciprocal	$0.007419 + 0.0^53478X$	0.451
	Log-log	$9.4512 - 0.6670X$	0.367
No. of seeds per pod	Arithmetic	$1.7874 - 0.0^43596X$	0.268
	Logarithmic	$0.5787 - 0.0^42203X$	0.265
	Reciprocal	$0.5616 + 0.0^41366X$	0.261
	Log-log	$1.2736 - 0.09525X$	0.135
Wt. of seeds per plant	Arithmetic	$16.0260 - 0.002874X + 0.0^61776X^2$	0.659
	Logarithmic	$2.7018 - 0.0^31803X$	0.634
	Reciprocal	$0.08137 + 0.0^83761X$	0.322
	Log-log	$7.4773 - 0.6738X$	0.334

^aArithmetic: $Y = a + bX$ or $Y = a + bX + cX^2$

Logarithmic: $\log Y = a + bX$

Reciprocal: $1/Y = a + bX$

Log-log: $\log Y = a + b \log X$.

^bIn fitting the logarithmic models, natural logarithms were used.

^cSignificant at the 5% probability level.

^d0.0⁴3192 is read 0.00003192.

Figure 11. Soybean pods per plant as influenced by sicklepod density

Circles represent average of four replications for the various soybean row distances.

Figure 12. Soybean seeds per plant as affected by sicklepod density

Circles represent average of four replications for the various soybean row distances.

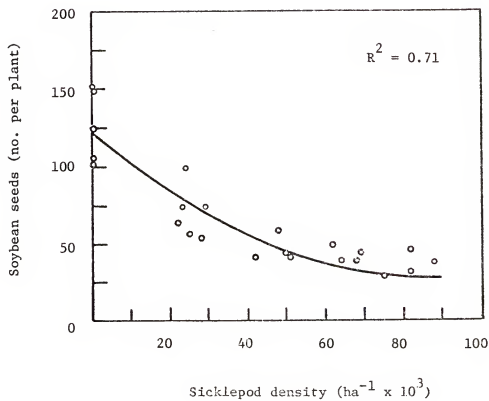
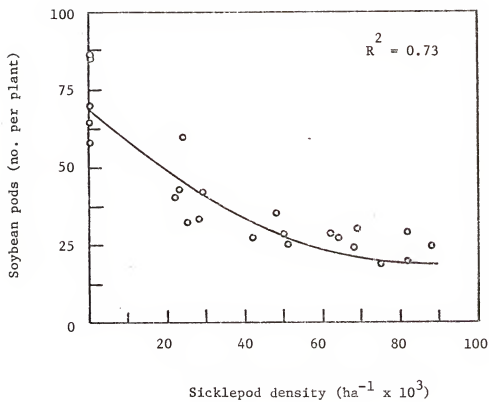
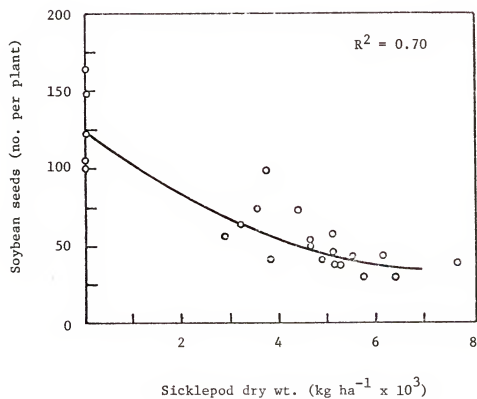
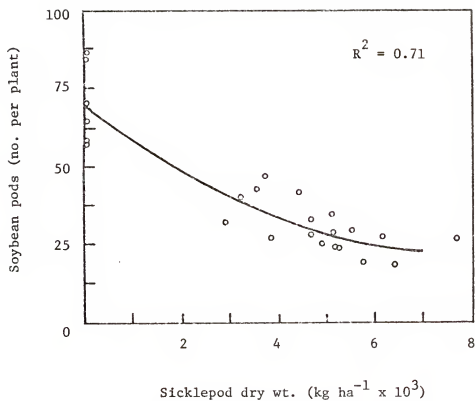


Figure 13. Soybean pods per plant as influenced by dry weight of sicklepod

Circles represent average of four replications for the various soybean row distances.

Figure 14. Soybean seeds per plant as affected by dry weight of sicklepod

Circles represent average of four replications for the various soybean row distances.



Seed weight per plant. Yields of seeds per soybean plant were reduced by increased levels of sicklepod density, but there was no statistical difference between the medium and high weed infestations (Table 13).

Soybean seed weight per plant decreased 44, 63, and 69% for low, medium, and high sicklepod densities, respectively (Figure 9). From arithmetic equations in Tables 14 and 15, the effects of sicklepod density and dry weight production on soybean seed yield per plant are shown in Figures 15 and 17.

When soybeans were grown in rows 90 cm apart, the seed weight per plant was significantly higher than for soybeans in the narrower rows of 45 and 30-60 cm (Table 13, Figure 10). Soybeans in 60-cm row widths presented intermediate seed yields per plant.

Greater differences in seed yield per plant were obtained among row distances under weed-free conditions than for the low sicklepod infestation (Figure 23). These differences almost disappeared for medium and high sicklepod levels.

Comparison between soybean seed yield per plant with sicklepod dry weight per plant, as a function of the weed density, is presented in Figure 20.

Seed size. Under weed-free conditions and medium sicklepod density no significant differences among row distances were found in regard to weight of 100 seeds (Table 16).

With low sicklepod density, seed size tended to increase in the 60-cm rows; and under high weed density, weight of 100 seeds showed the tendency to decrease in rows 60 cm apart (Table 16).

Figure 15. Soybean seed yield per plant as affected by sicklepod density

Circles represent average of four replications for the various soybean row distances.

Figure 16. Soybean seed yield per area as influenced by sicklepod density

Circles represent average of four replications for the various soybean row distances.

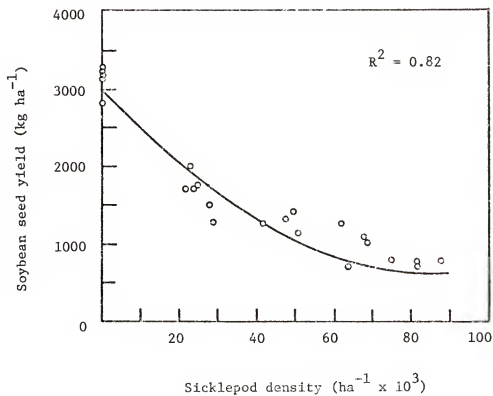
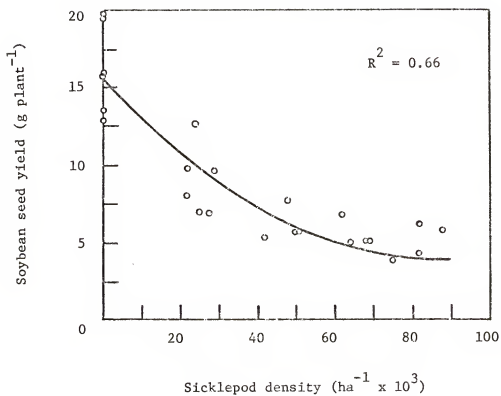


Figure 17. Soybean seed yield per plant as affected by dry weight of sicklepod

Circles represent average of four replications for the various soybean row distances.

Figure 18. Soybean seed yield per area as influenced by dry weight of sicklepod

Circles represent average of four replications for the various soybean row distances.

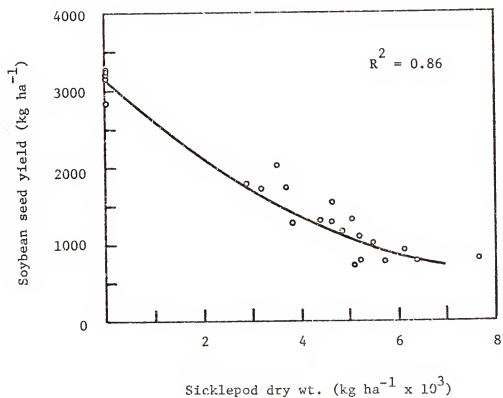
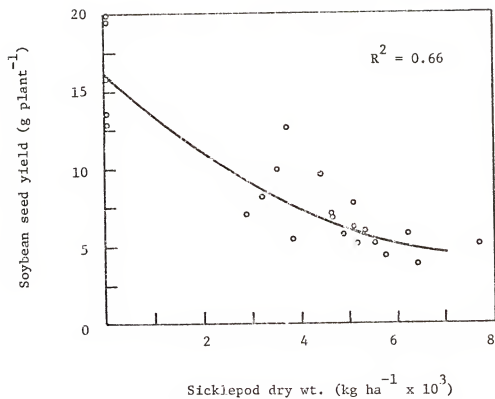


Figure 19. Response of soybean seed yield and sicklepod dry weight to sicklepod density

Circles represent average of four replications for the various soybean row distances.

Figure 20. Effect of sicklepod density on soybean seed yield per plant and sicklepod dry weight per plant; presented in logarithmic scales

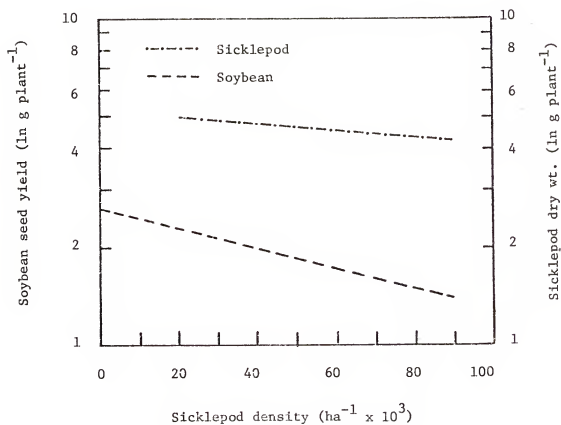
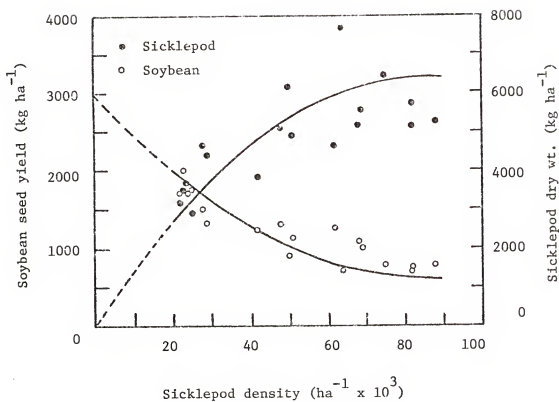


Figure 21. Soybean pods per plant as influenced by the final soybean populations resulting from the various row distances, and modified by the presence of sicklepod

Figure 22. Soybean seeds per plant as affected by the final soybean populations resulting from the various row distances, and modified by the presence of sicklepod

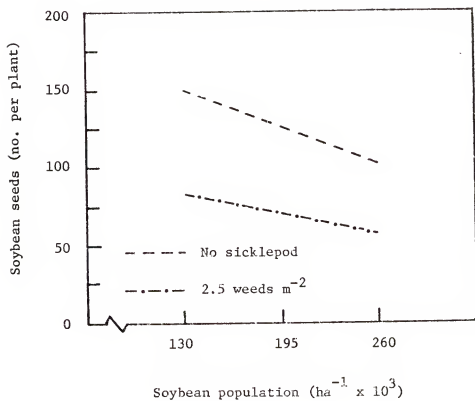
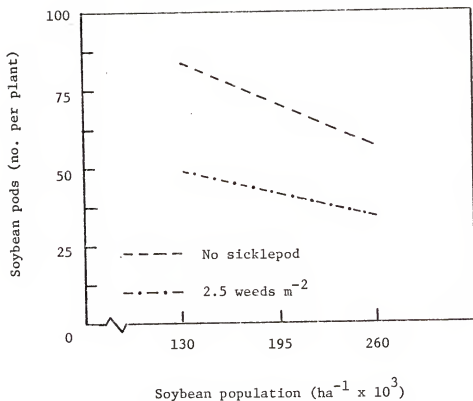


Figure 23. Soybean seed yield per plant as affected by the final soybean populations resulting from the various row distances, and modified by the presence of sicklepod

Figure 24. Sicklepod dry weight per plant and soybean seed yield per area as influenced by the final soybean populations resulting from the various row distances

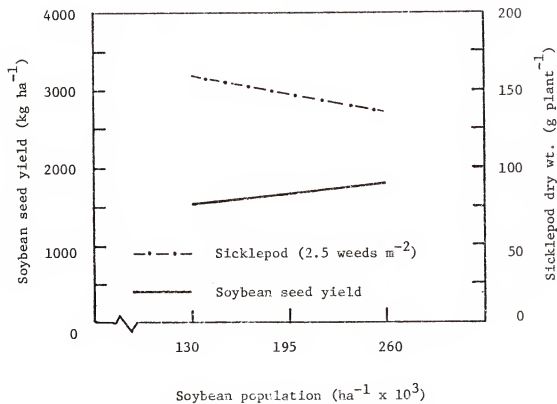
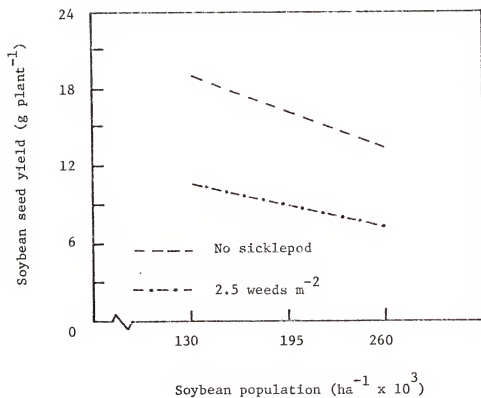


Table 16. Effect of sicklepod densities and soybean row distances on the weight (g) of 100 soybean seeds in experiment 1^{ab}

Soybean row distances	Sicklepod densities (per ha)			
	None	25,000	53,000	77,000
90 cm	^b 13.00 ^e	^b 13.14 ^{ef}	^b 13.00 ^e	^a 14.96 ^e
60 cm	^a 12.77 ^e	^a 14.00 ^e	^a 13.96 ^e	^a 12.87 ^{fg}
45 cm	^{ab} 12.85 ^e	^b 12.37 ^f	^a 13.98 ^e	^{ab} 13.43 ^f
30 to 90 cm	^a 12.96 ^e	^a 12.87 ^{ef}	^a 13.06 ^e	^a 13.76 ^{ef}
30 to 60 cm	^{ab} 12.96 ^e	^a 13.44 ^{ef}	^{ab} 13.02 ^e	^b 11.65 ^g
30 to 30-60 cm	^a 12.85 ^e	^a 12.36 ^f	^a 12.94 ^e	^a 13.24 ^f

^aMeans within a row preceded by the same letter, or means within a column followed by the same letter are not significantly different at the 5% probability level, as determined by Duncan's multiple range test.

^bValues are average of four replications.

For soybeans in 90-cm rows throughout the season, bigger seeds were produced under high sicklepod infestation; and for soybeans in rows constantly at 45 cm, bigger seeds tended to occur in the medium weed density (Table 16). For the variable row system, soybeans in 60-cm rows tended to present heavier seeds under low sicklepod density. The general trend was for the occurrence of heavier seeds under weed competition conditions (Table 13). There was also a tendency for bigger seeds to develop in the constant row system than in the variable pattern.

Number of pods, number of seeds, seed weight per plant, and seeds per pod, in this order, were all negative and highly correlated with sicklepod ground cover, leaf area index, density, and dry matter (Table 19). Correlation coefficients increased as the season progressed.

Seed size was less associated with the sicklepod parameters measured, and when correlations occurred, they were positive. None of these seed yield components was associated with soybean ground cover and leaf area index 4 and 6 weeks after planting. However, all variables were positively correlated with number of branches, number of nodes, and stem diameter of soybean plants; except seed size, which was correlated only with soybean nodes. Number of seeds per pod and weight of 100 seeds were associated with soybean height, the other yield components were not.

The seed yield components were positively correlated among themselves; except seed size, which only showed a slight association with number of seeds per pod.

Seed yield

Soybean seed yields were significantly reduced as the level of sicklepod density increased (Table 13). Yields decreased 47, 65, and 73% for the low, medium, and high weed densities, respectively (Figure 9).

Graphic presentations of the influences of sicklepod density or sicklepod dry weight on soybean seed yield are seen in Figures 16 and 18, calculated from the arithmetic equations contained in Tables 14 and 15. Figure 19 shows the relationship between soybean seed yield per area and sicklepod dry weight per area, as functions of the weed density.

Soybeans grown in row spacings of 90 cm in either system yielded less than those cultivated at 60-cm or 30-60-cm rows in the variable pattern. Constant row widths of 60 and 45 cm had intermediate seed

productions (Table 13, Figure 10). The general tendency, as shown in Figure 24 (from the estimated equation of Table 17), was for the yields to increase as soybean row widths decreased.

Table 17. Estimated regression equations for soybean yield and components of yield, and sicklepod dry weight, as dependent on final soybean populations and affected by sicklepod densities^a

Dependent variables	Sicklepod densities	Regression equations ^{bc}
No. of pods/plant	None	110.902 - 13.581P
	2.5 weeds/m ²	63.465 - 7.344P
No. of seeds/plant	None	197.18 - 23.83P
	2.5 weeds/m ²	108.64 - 12.91P
Wt. of seeds/plant	None	25.799 - 3.192P
	2.5 weeds/m ²	14.453 - 1.801P
Soybean seed yield	(independent)	1270.88 + 134.16P
Sicklepod dry wt./plant	2.5 weeds/m ²	182.24 - 11.70P

^aFinal soybean populations were 130,000, 195,000, and 260,000 per ha for the 90, 60, and 45 or 30-60 cm row distances, respectively.

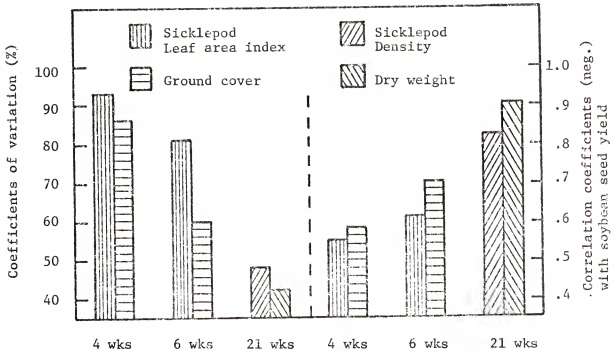
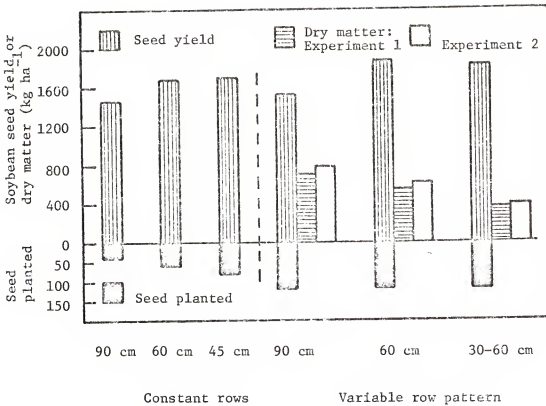
^bIndependent variable P is the final population divided by 65,000.

^cSignificant at the 5% probability level.

Figure 25 shows that row distances of 60 and 30-60 cm in variable spacing provided the highest soybean seed yields, and the variable system of 90-cm rows produced the highest amount of dry matter 5 weeks after planting.

Figure 25. Comparison between amounts of soybean seeds planted (kg ha^{-1}), seed yielded, and dry matter produced for the various soybean row distance systems

Figure 26. Comparison between coefficients of variation and correlation coefficients for sicklepod leaf area index, ground cover, density, and dry weight at various times, in experiment 1



However, the variable row pattern required greater quantities of seeds at planting. Although there were no differences between constant row spacings with respect to seed yields, the amount of seeds needed for planting decreased with wider rows. If the seeding rates are deducted from seed yields, the differences in yield among the various row widths, and mainly between patterns, generally decrease, but rows 90 cm apart still remain as the lower seed yield producers.

Soybean seed yield was negatively associated with the sicklepod variables measured (Table 19). As seen in Figure 26, the coefficients of variation tended to decrease, and the correlation coefficients to increase with advancing of the growing season. Seed yields were correlated with soybean ground cover and leaf area index 6 weeks after planting. Soybean yields were also associated with soybean plant characteristics (branches, nodes, and diameter), except height. Soybean seed yields were highly correlated with seed yield components, with the exception of seed size.

A multiple regression equation relating soybean seed yield with the independent variables number of pods per plant, number of seeds per plant, number of seeds per pod, weight of seeds per plant, and weight of 100 seeds was found to be

$$\text{Yield (kg/ha)} = 41.66 X_1 - 4.83 X_2 + 1570.34 X_3 - 2294.55$$

being: X_1 = number of pods per plant;

X_2 = number of seeds per plant; and

X_3 = number of seeds per pod.

Weight of seeds per plant and weight of 100 seeds did not improve the

fit of the regression equation. The contribution of all other independent variables was significant at the 5% level or better. The relationship was found to explain 79.3% of the observed variation in soybean seed yield.

In addition, an analysis was performed to determine if a significant difference existed between "expected" and "observed" soybean seed yields. The value of t obtained, based on 95 degrees of freedom, was 2.3 which is significant at the 5% level. The "observed" yields were found to average 82 kg/ha (approximately 5%) less than the "expected" yields.

Soil nutrients

No significant differences concerning soil levels of phosphorus, potassium, calcium, and magnesium were detected as a result of the various competing populations of sicklepod and soybean over the area (Table 18).

Seedlings

From greenhouse experiments, no statistical differences were obtained for soybean germination and fresh weight of seedlings in relation to the treatments tested in the field (Table 18).

Generally, symmetrical correlation coefficients occurred between germination and vigor of soybean seedlings for most of the variables measured in the field experiment (Table 19). However, seed germination and seedling vigor were both positively associated with plant height and seed size.

Table 18. Influence of sicklepod densities and soybean row distance on soil nutrients, soybean germination, and seedling vigor in experiment 1^a

Factors	Soil nutrients content ^b				Soybean seedlings ^c	
	Phosphorus (ppm)	Potassium (ppm)	Calcium (ppm)	Magnesium (ppm)	Germination (%)	Fresh weight (g/plant)
Sicklepod/ha: ^d						
None	21.78 ^a	112.6 ^a	444.7 ^a	177.4 ^a	90.00 ^a	1.090 ^a
25,000	21.79 ^a	112.1 ^a	462.8 ^a	170.9 ^a	92.71 ^a	1.073 ^a
53,000	21.21 ^a	109.6 ^a	461.7 ^a	195.6 ^a	88.75 ^a	1.102 ^a
77,000	21.10	110.2 ^a	440.5 ^a	203.6 ^a	88.33 ^a	1.149 ^a
Row distances: ^e						
90 cm	21.89 ^e	112.5 ^e	446.1 ^e	179.5 ^e	86.25 ^e	1.107 ^e
60 cm	20.81 ^e	112.8 ^e	452.4 ^e	191.4 ^e	89.38 ^e	1.151 ^e
45 cm	22.46 ^e	109.6 ^e	456.4 ^e	191.4 ^e	90.62 ^e	1.101 ^e
30 to 90 cm	21.38 ^e	109.8 ^e	467.0 ^e	198.0 ^e	92.19 ^e	1.084 ^e
30 to 60 cm	20.72 ^e	111.0 ^e	437.2 ^e	171.6 ^e	89.69 ^e	1.077 ^e
30 to 30-60 cm	21.54 ^e	111.0 ^e	455.5 ^e	189.4 ^e	91.56 ^e	1.101 ^e
Overall mean	21.47	111.1	452.4	186.9	89.95	1.104

^aMeans within columns followed by the same letter do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

^bAt harvest time.

^cOne month after harvesting

^dValues are average of four replications, across soybean row distances.

^eValues are average of four replications, across sicklepod densities.

Table 19. Simple correlation coefficients among variables from experiment 1

Soybean						
Variables	GC at 4 wks	GC at 6 wks	LA at 4 wks	LA at 6 wks	Perc. germ.	Seedl. wt.
Sic. GC 4 wks	-.066 NS	-.173 NS	-.048 NS	-.190 NS	-.133 NS	.095 NS
Sic. GC 6 wks	-.310 **	-.214 *	-.314 **	-.178 NS	-.103 NS	.167 NS
Sic. LA 4 wks	-.097 NS	-.116 NS	-.075 NS	-.124 NS	-.093 NS	.154 NS
Sic. LA 6 wks	-.271 **	-.169 NS	-.286 **	-.103 NS	-.080 NS	.223 *
Sic. plants/ha	-.241 *	-.247 *	-.235 *	-.158 NS	-.086 NS	.303 **
Sic. dry wt./ha	-.173 NS	-.358 **	-.178 NS	-.315 **	-.075 NS	.066 NS
Soy. GC 4 wks	---	.128 NS	.928 **	.607 NS	.211 *	-.176 NS
Soy. GC 6 wks	.128 NS	---	.138 NS	.867 **	-.065 NS	.118 NS
Soy. LA 4 wks	.928 **	.138 NS	---	.018 NS	.268 **	-.185 NS
Soy. LA 6 wks	.007 NS	.867 **	.018 NS	---	-.034 NS	.218 *
Soy. perc. germ.	.211 *	-.065 NS	.268 **	-.034 NS	---	.064 NS
Soy. seedl. wt.	-.176 NS	.118 NS	-.185 NS	.218 *	.064 NS	---
Soy. branches	-.004 NS	-.231 *	.001 NS	-.168 NS	.089 NS	-.176 NS
Soy. nodes	-.114 NS	.132 NS	-.098 NS	.211 *	.281 **	.100 NS
Soy. diameter	.015 NS	-.071 NS	.018 NS	.020 NS	.196 NS	-.210 *
Soy. height	.036 NS	.559 NS	.069 NS	.583 **	.205 *	.284 **
Soy. seed yld.	.149 NS	.304 **	.158 NS	.298 **	.172 NS	-.109 NS
Soy. no. pods	.141 NS	.032 NS	.141 NS	.082 NS	.143 NS	-.185 NS
Soy. no. seeds	.099 NS	.050 NS	.097 NS	.098 NS	.171 NS	-.183 NS
Soy. seeds/pod	-.024 NS	.120 NS	-.017 NS	.134 NS	.296 **	-.147 NS
Soy. seed wt.	.080 NS	.047 NS	.082 NS	.110 NS	.187 NS	-.131 NS
Soy. 100 seeds	-.168 NS	-.023 NS	-.151 NS	.093 NS	.238 *	.582 **

Table 19. Continued

Variables	Soybean				
	No. branches	No. nodes	Stem diameter	Stem height	Seed yield
Sic. GC 4 wks	-.323 **	-.239 *	-.395 **	-.097 NS	-.579 **
Sic. GC 6 wks	-.281 **	-.206 *	-.492 **	-.102 NS	-.700 **
Sic. LA 4 wks	-.343 **	-.234 *	-.409 **	-.056 NS	-.552 **
Sic. LA 6 wks	-.244 *	-.148 NS	-.451 **	-.052 NS	-.613 **
Sic. plants/ha	-.428 **	-.271 **	-.514 **	-.120 NS	-.817 **
Sic. dry wt./ha	-.444 **	-.336 **	-.614 **	-.137 NS	-.900 **
Soy. GC 4 wks	-.004 NS	-.114 NS	.015 NS	.036 NS	.149 NS
Soy. GC 6 wks	-.231 *	.132 NS	-.071 NS	.559 **	.304 **
Soy. LA 4 wks	.001 NS	-.098 NS	.018 NS	.069 NS	.158 NS
Soy. LA 6 wks	-.168 NS	.211 *	.020 NS	.583 **	.298 **
Soy. perc. germ.	.089 NS	.281 **	.196 NS	.205 *	.172 NS
Soy. seedl. wt.	-.176 NS	.100 NS	-.210 *	.284 **	-.109 NS
Soy. branches	---	.199 NS	.749 **	-.327 **	.478 **
Soy. nodes	.199 NS	---	.546 **	.568 **	.408 **
Soy. diameter	.749 **	.546 **	---	.041 NS	.687 **
Soy. height	-.327 **	.568 **	.041 NS	---	.194 NS
Soy. seed yld.	.478 **	.408 **	.687 **	.194 NS	.862 **
Soy. no. pods	.695 **	.423 **	.869 **	-.001 NS	.879 **
Soy. no. seeds	.650 **	.457 **	.866 **	.049 NS	.625 **
Soy. seeds/pod	.203 *	.500 **	.492 **	.305 **	.873 **
Soy. seed wt.	.643 **	.498 **	.870 **	.088 NS	.873 **
Soy. 100 seeds	-.040 NS	.364 **	.063 NS	.374 **	-.017 NS

Table 19. Concluded

Variables	Soybean				
	Pods/plant	Seeds/plant	Seeds/pod	Seed wt./plant	Wt. 100 seeds
Sic. GC 4 wks	-.511 **	-.508 **	-.379 **	-.497 **	.053 NS
Sic. CC 6 wks	-.636 **	-.632 **	-.404 **	-.599 **	.211 *
Sic. LA 4 wks	-.505 **	-.502 **	-.386 **	-.492 **	.073 NS
Sic. LA 6 wks	-.572 **	-.561 **	-.311 **	-.522 **	.261 *
Sic. plants/ha	-.778 **	-.761 **	-.464 **	-.725 **	.206 *
Sic. dry wt./ha	-.802 **	-.797 **	-.518 **	-.780 **	.042 NS
Soy. GC 4 wks	.141 NS	.099 NS	-.024 NS	.080 NS	-.168 NS
Soy. GC 6 wks	.032 NS	.050 NS	.120 NS	.047 NS	-.023 NS
Soy. LA 4 wks	.141 NS	.097 NS	-.017 NS	.082 NS	-.151 NS
Soy. LA 6 wks	.082 NS	.098 NS	.134 NS	.110 NS	.093 NS
Soy. perc. germ.	.143 NS	.171 NS	.296 **	.187 NS	.238 *
Soy. seedl. wt.	-.185 NS	-.183 NS	-.147 NS	-.131 NS	.582 **
Soy. branches	.695 **	.650 **	.203 *	.643 **	-.040 NS
Soy. nodes	.423 **	.457 **	.500 **	.498 **	.364 **
Soy. diameter	.869 **	.866 **	.492 **	.870 **	.063 NS
Soy. height	-.001 NS	.049 NS	.305 **	.088 NS	.374 **
Soy. seed yld.	.862 **	.879 **	.625 **	.873 **	-.017 NS
Soy. no. pods	---	.984 **	.500 **	.971 **	-.075 NS
Soy. no. seeds	.984 **	---	.622 **	.994 **	-.041 NS
Soy. seeds/pod	.500 **	.622 **	---	.645 **	.215 *
Soy. seed wt.	.971 **	.994 **	.645 **	.645 **	.049 NS
Soy. 100 seeds	-.075 NS	-.041 NS	.215 *	---	---

Experiment 2

Eighteen responses were measured in this experiment. Appendix Table B summarizes the results of the analyses of variance. Only mean squares are presented, with significant effects indicated by asterisks after the appropriate mean squares.

From the results of the analyses of variance, it will be observed that 12 responses had significant differences among sicklepod densities and 12 responses were significantly affected by row distances. There was only one response which was unaffected by either experimental factor, while seven responses showed significant differences due to both. Of the latter set, four had significant density x row distance interactions.

Main effect means associated with these analyses and results of Duncan's test performed on the density and row distance means are provided in Tables 20, 22, and 26. Tables 21, 23, 24, and 25 investigate the nature of the interaction effect for the four responses for which the density x row distance interaction was significant. Presented in these tables are the interaction means and the results of Duncan's test on the means of one factor for all levels of the second.

Estimated linear correlations between all possible pairs of responses are presented in Table 27.

SicklepodGround cover and leaf area index

Sicklepod ground cover and leaf area index, 4 and 5 weeks after soybean planting date, increased as with the weed density (Table 20 and

Table 20. Response of sicklepod ground cover and leaf area index to sicklepod densities and soybean row distances in experiment 2

Factors	Sicklepod ^a					
	Percentage ground cover ^b			Leaf area index ^b		
	4 weeks	5 weeks	7 weeks	4 weeks	5 weeks	7 weeks ^c
Sicklepod/ha: ^d						
None	0.00 ^c	0.00 ^c	0.00 ^c	0.000 ^c	0.000 ^c	0.000
36,000	2.43	5.21 ^{bc}	11.11 ^b	0.024 ^{bc}	0.055 ^{bc}	0.167
68,000	6.94 ^{ab}	9.03 ^{ab}	18.40 ^b	0.069 ^b	0.115 ^b	0.302
122,000	10.76	15.63 ^a	34.72 ^a	0.122 ^a	0.212 ^a	0.615
Row distances: ^e						
90 cm	6.25 ^e	7.29 ^e	17.19 ^e	0.068 ^e	0.078 ^e	0.292
60 cm	4.69 ^e	10.42 ^e	20.83 ^e	0.052 ^e	0.135 ^e	0.370
45 cm	3.64 ^e	5.21 ^e	13.54 ^e	0.036 ^e	0.078 ^e	0.219
30 to 90 cm	4.69 ^e	5.73 ^e	16.15 ^e	0.052 ^e	0.078 ^e	0.276
30 to 60 cm	3.65 ^e	6.77 ^e	10.42 ^e	0.042 ^e	0.078 ^e	0.167
30 to 30-60 cm	7.29 ^e	9.38 ^e	18.23 ^e	0.073 ^e	0.125 ^e	0.302
Overall means	5.03	7.47	16.06	0.054	0.095	0.271

^a Means within columns followed by the same letter do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

^b Time after soybean planting date.

^c Interaction sicklepod densities x soybean row distances present.

^d Values are average of four replications, across soybean row distances.

^e Values are average of four replications, across sicklepod densities.

Figure 2). However, no differentiation occurred between weed-free and low sicklepod density, and also between low and medium weed infestations. At those times, sicklepod ground cover and leaf area were statistically the same for soybean row distance treatments.

Sicklepod ground cover at 7 weeks was highest for the high weed density (Table 20). Values obtained for low and medium densities still were statistically similar. Similar responses concerning sicklepod ground cover were obtained for soybean row spacings.

At 7 weeks, values obtained for sicklepod leaf area index at the high density significantly increased for soybean row widths of 60 cm throughout the season, and for the variable spacings of 90- and 30-60-cm rows (Table 21). These same treatments also presented significantly higher indexes for the high weed density in relation to the medium infestation.

Soybean

Ground cover and leaf area index

Four weeks after planting, soybean ground cover tended to be reduced in the weedy treatments in comparison with sicklepod-free, specially the low sicklepod density (Table 22). However, at this stage, no statistical differences were found for soybean leaf area index in relation to sicklepod infestations.

Ground cover and leaf area of soybeans 4 weeks after planting were highest for the variable row pattern (unaltered 30 cm spacing), and lowest for soybeans at 90- and 60-cm rows since the beginning (Table 22, Figures 27 and 28).

Table 21. Effect of sicklepod densities and soybean row distances on sicklepod leaf area index at 7 weeks in experiment 2^{abc}

Soybean row distances	Sicklepod densities (per ha)			
	None	36,000	68,000	122,000
90 cm	b _{0.0} ^e	ab _{0.229} ^e	a _{0.479} ^e	a _{0.458} ^f
60 cm	c _{0.0} ^e	bc _{0.188} ^e	b _{0.417} ^e	a _{0.875} ^e
45 cm	b _{0.0} ^e	ab _{0.250} ^e	ab _{0.250} ^e	a _{0.375} ^f
30 to 90 cm	b _{0.0} ^e	b _{0.083} ^e	b _{0.208} ^e	a _{0.812} ^e
30 to 60 cm	b _{0.0} ^e	b _{0.042} ^e	ab _{0.250} ^e	a _{0.375} ^f
30 to 30-60 cm	b _{0.0} ^e	b _{0.208} ^e	b _{0.208} ^e	a _{0.792} ^e

^aMeans within a row preceded by the same letter, or means within a column followed by the same letter are not significantly different at the 5% probability level, as determined by Duncan's multiple range test.

^bValues are average of four replications.

^cTime after soybean planting date.

Soybean ground cover at 5 weeks was highest for plants in the narrow rows of 45 and 30-60 cm under weed-free conditions and low sicklepod density. With medium and high sicklepod densities, ground cover generally was small in the 90-cm row treatments. Ground cover of soybeans constantly in 45-cm rows was significantly higher in weed-free conditions than under sicklepod competition (Table 23). Variable row widths of 90 and 30-60 cm apart developed higher soybean ground cover percentages in weed-free plots than under high competition with sicklepod.

With no sicklepod present, soybean leaf area index at 5 weeks was highest in the 45-cm row spacing; and under low weed infestation, soybeans in the variable system of 30-60-cm rows developed the highest

Table 22. Response of soybean ground cover and leaf area index to sicklepod densities and soybean row distances in experiment 2

Factors	Soybean ^a					
	Percentage ground cover ^b			Leaf area index ^b		
	4 weeks	5 weeks ^c	7 weeks ^c	4 weeks	5 weeks ^c	7 weeks
Sicklepod/ha: ^d						
None	51.04 ^a	45.14	65.97	0.785 ^a	0.729	1.507 ^a
36,000	38.20 ^b	35.76	62.50	0.531 ^a	0.521	1.299 ^a
68,000	40.9 ^{ab}	36.81	63.54	0.580 ^a	0.538	1.392 ^a
122,000	40.97 ^{ab}	33.33	63.20	0.601 ^a	0.528	1.306 ^a
Row distances: ^e						
90 cm	20.31 ^g	30.21	49.48	0.333 ^g	0.484	1.146 ^{gh}
60 cm	28.65 ^g	37.50	66.67	0.349 ^g	0.589	1.401 ^{fg}
45 cm	42.19 ^f	51.56	82.81	0.651 ^f	0.844	1.927 ^e
30 to 90 cm	51.56 ^e	25.00	46.87	0.745 ^{ef}	0.339	0.943 ^h
30 to 60 cm	58.33 ^e	36.98	67.71	0.807 ^{ef}	0.547	1.333 ^{fg}
30 to 30-60 cm	55.73 ^e	45.31	69.27	0.859 ^e	0.672	1.505 ^f
Overall means	42.80	37.76	63.80	0.624	0.579	1.376

^aMeans within columns followed by the same letter do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

^bTime after soybean planting date.

^cInteraction sicklepod densities x soybean row distances present.

^dValues are average of four replications, across soybean row distances.

^eValues are average of four replications, across sicklepod densities.

Figure 27. Soybean leaf area index as influenced by row distance patterns at three times during the growing season, in experiment 2

Figure 28. Soybean ground cover as influenced by row distance patterns at three times during the growing season, in experiment 2

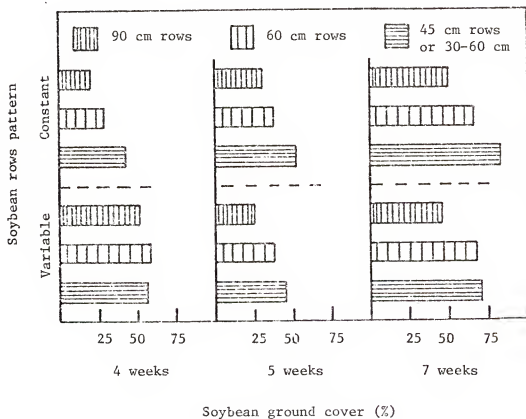
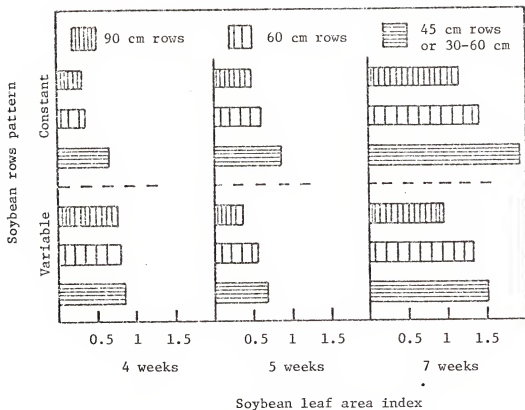


Table 23. Effect of sicklepod densities and soybean row distances on soybean ground cover (%) at 5 weeks in experiment 2^{abc}

Soybean row distances	Sicklepod densities (per ha)			
	None	36,000	68,000	122,000
90 cm	^a 37.50 ^{fg}	^a 29.17 ^f	^a 25.00 ^f	^a 29.17 ^{ef}
60 cm	^a 39.58 ^{fg}	^a 29.17 ^f	^a 41.66 ^{ef}	^a 39.58 ^e
45 cm	^a 72.92 ^e	^b 50.00 ^e	^b 41.67 ^{ef}	^b 41.66 ^e
30 to 90 cm	^a 35.42 ^g	^{ab} 22.92 ^f	^{ab} 27.08 ^f	^b 14.58 ^f
30 to 60 cm	^a 31.25 ^g	^a 29.17 ^f	^a 45.84 ^e	^a 41.67 ^e
30 to 30-60 cm	^a 54.17 ^f	^a 54.17 ^e	^{ab} 39.58 ^{ef}	^b 33.33 ^e

^a Means within a row preceded by the same letter, or means within a column followed by the same letter are not significantly different at the 5% probability level, as determined by Duncan's multiple range test.

^b Data are average of four replications.

^c Time after soybean planting date.

index (Table 24). At high sicklepod density, leaf area index of soybeans was higher in row distances of 60 and 45 cm for the constant pattern, and 60 cm for the variable row system. The lowest LAI tended to be produced in soybeans at the variable row pattern of 90 cm. Soybeans in the narrower rows of 45 and 30-60 cm developed more leaf area under weed-free conditions than under the higher sicklepod densities.

Soybean ground cover at 7 weeks was generally low for the 90-cm row spacings under all sicklepod densities (Table 25). And, faster ground cover was generally produced by soybeans in the narrower rows of

Table 24. Effect of sicklepod densities and soybean row distances on soybean leaf area index at 5 weeks in experiment 2^{abc}

Soybean row distances	Sicklepod densities (per ha)			
	None	36,000	68,000	122,000
90 cm	^a 0.625 ^{fg}	^a 0.396 ^{fg}	^a 0.438 ^e	^a 0.479 ^{ef}
60 cm	^a 0.542 ^{fg}	^a 0.500 ^{efg}	^a 0.646 ^e	^a 0.667 ^e
45 cm	^a 1.396 ^e	^b 0.729 ^{ef}	^b 0.604 ^e	^b 0.646 ^e
30 to 90 cm	^a 0.438 ^g	^a 0.271 ^g	^a 0.396 ^e	^a 0.250 ^f
30 to 60 cm	^a 0.479 ^g	^a 0.375 ^{fg}	^a 0.688 ^e	^a 0.646 ^e
30 to 30-60 cm	^a 0.896 ^f	^a 0.854 ^e	^b 0.458 ^e	^b 0.479 ^{ef}

^aMeans within a row preceded by the same letter, or means within a column followed by the same letter are not significantly different at the 5% level of probability as determined by Duncan's multiple range test.

^bValues are average of four replications.

^cTime after soybean planting date.

45 and 30-60 cm, except for the medium weed density where rows of 30-60 cm showed poor soil coverage (Table 25).

Soybeans at constant 60-cm rows presented significantly more ground cover for weed-free than with high sicklepod competition. Ground cover of soybeans under the variable pattern was reduced, as compared to weed-free situation, for row widths of 90 cm at low sicklepod density, and for 30-60-cm rows at the medium weed infestation. However, the soil coverage of soybeans grown in the variable system of 60-cm rows was lower under weed-free conditions.

At 7 weeks, equivalent indexes were measured for leaf area of soybeans under the various levels of sicklepod infestation (Table 22).

Table 25. Effect of sicklepod densities and soybean row distances on soybean ground cover (%) at 7 weeks in experiment 2^{abc}

Soybean row distances	Sicklepod densities (per ha)			
	None	36,000	68,000	122,000
90 cm	^a 54.16 ^f	^a 45.83 ^f	^a 45.83 ^f	^a 52.08 ^f
60 cm	^a 75.00 ^e	^{ab} 66.66 ^e	^{ab} 72.92 ^e	^b 52.08 ^f
45 cm	^a 83.34 ^e	^a 81.25 ^e	^a 81.25 ^e	^a 85.42 ^e
30 to 90 cm	^a 56.25 ^f	^b 39.58 ^f	^{ab} 47.92 ^f	^{ab} 43.75 ^f
30 to 60 cm	^b 50.00 ^f	^a 68.75 ^e	^a 77.08 ^e	^a 75.00 ^e
30 to 30-60 cm	^a 77.08 ^e	^a 72.92 ^e	^b 56.25 ^f	^{ab} 70.84 ^e

^a Means within a row preceded by the same letter, or means within a column followed by the same letter, are not significantly different at the 5% probability level, as determined by Duncan's multiple range test.

^b Data are average of four replications.

^c Time after soybean planting date.

The highest leaf area index was developed by soybeans in the row spacing of 45 cm throughout the season, while the lowest indexes were measured in the row widths of 90 cm (Figure 27).

Negative coefficients among sicklepod ground cover and leaf area with ground cover and leaf area of soybean were generated, but these associations generally were not significant. However, sicklepod ground cover and leaf area at 7 weeks was slightly and negatively correlated with soybean ground cover and leaf area at 5 weeks (Table 27).

Dry matter

Soybean dry matter produced at 5 weeks after planting was statistically similar under the different levels of sicklepod (Table 26). The variable row pattern yielded the highest quantity for soybeans in 90-cm rows, significantly less for 60-cm rows, and the lowest amount was produced at 30-60-cm row width.

Plant characteristics

Height. Soybean height was not modified by the various levels of sicklepod infestation (Table 26). Under the different row spacings, the tallest plants occurred at 45-cm rows throughout the season, and the shortest soybeans were those grown at the variable row system of 90 cm (Figure 30). Intermediate heights were measured in the other treatments. There was a trend for soybeans in the variable rows pattern to be shorter than the plants in the constant rows system.

Leaves. The number of leaves per soybean plant decreased with increasing sicklepod densities; however, statistically the same numbers were counted in plants under weed-free situation and low sicklepod infestation (Table 26, Figure 29).

Soybeans grown in the wider row widths of 90 cm presented more leaves than those planted in the closer distances of 45 and 30-60 cm (Figure 30).

Branches. Soybeans competing with the medium and high sicklepod densities produced significantly less branches than those in weed-free and low level of sicklepod (Table 26, Figure 29).

Table 26. Influence of sicklepod densities and soybean row distances on dry matter, height, and number of leaves, branches, nodes, and pods of soybeans in experiment 2^a

Factors	Dry matter ^b (kg/ha)	Soybean plant characters ^c				
		Stem height (cm)	Leaves (no.)	Branches (no.)	Nodes (no.)	Pods (no.)
Sicklepod/ha: ^d						
None	334.7 ^a	67.47 ^a	24.66 ^a	5.704 ^a	14.68 ^a	16.97 ^a
36,000	274.8 ^a	63.21 ^a	23.14 ^a	5.446 ^a	14.65 ^a	14.98 ^a
68,000	271.2 ^a	66.76 ^a	21.20 ^b	4.917 ^b	14.65 ^a	14.97 ^a
122,000	289.2 ^a	68.38 ^a	19.32 ^c	4.567 ^b	14.66 ^a	17.32 ^a
Row distances: ^e						
90 cm	0.0 ^h	65.24 ^{fg}	25.68 ^e	6.131 ^e	14.99 ^e	18.84 ^e
60 cm	0.0 ^h	67.88 ^{ef}	21.62 ^{fg}	5.244 ^f	14.84 ^{ef}	15.66 ^e
45 cm	0.0 ^h	70.62 ^e	19.62 ^{gh}	4.488 ^g	15.02 ^e	16.12 ^e
30 to 90 cm	785.2 ^e	63.85 ^g	23.81 ^{ef}	5.369 ^f	14.36 ^g	14.61 ^e
30 to 60 cm	597.8 ^f	64.60 ^{fg}	23.16 ^f	5.444 ^f	14.34 ^g	16.28 ^e
30 to 30-60 cm	371.8 ^g	66.54 ^{fg}	18.60 ^h	4.275 ^g	14.42 ^{fg}	14.85 ^e
Overall means	292.5	66.45	22.08	5.158	14.66	16.06

^aMeans within columns followed by the same letter do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

^bAt 5 weeks after soybean planting date.

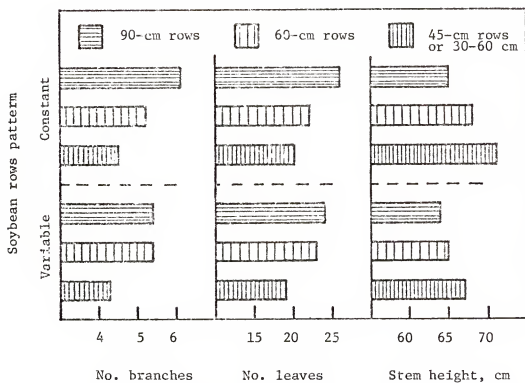
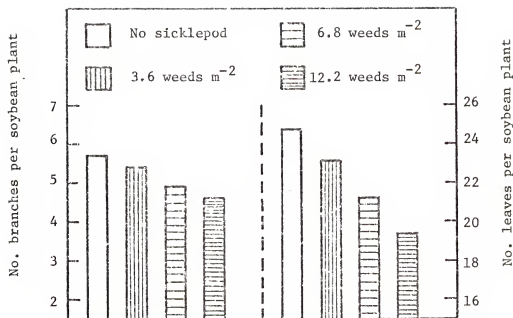
^cAt 3 months after soybean planting date.

^dValues are average of four replications, across soybean row distances.

^eValues are average of four replications, across sicklepod densities.

Figure 29. Number of branches and leaves per soybean plant
3 months after planting, as influenced by sicklepod
densities, in experiment 2

Figure 30. Number of branches and leaves, and stem height of
soybeans 3 months after planting, at various row
distance patterns, in experiment 2



For soybean row distances, plants constantly at 90-cm rows presented the highest number of branches, while those in the closer spacings of 45 cm and 30-60 cm were the least branched (Figure 30). The remainder treatments had intermediate number of branches on the main stem.

Nodes. No significant differences in the number of nodes per soybean plant were found in regard to sicklepod densities (Table 26). The major trend for soybean row distances in relation to node number was for those in the constant row pattern to develop more nodes than plants in the variable row system.

Pods. Three months after planting, when soybeans were at the reproductive stage 4 (pod 2 cm long at one of the four uppermost nodes with a completely unrolled leaf) no differences were found in respect to the number of pods per soybean plant (Table 26).

Generally, the number of leaves and number of branches of soybeans were negatively correlated with sicklepod ground cover and leaf area, and also with the weed density (Table 27). The correlation coefficients tended to increase as the growing season progressed.

Soybean height was positively associated with those sicklepod variables measured. Number of nodes and number of pods were not correlated with sicklepod ground cover, leaf area, or density.

Soybean height was positive and highly correlated with soybean ground cover and leaf area index evaluated at 4, 5, and 7 weeks after planting. Number of branches and number of leaves tended to be negatively correlated with soybean ground cover and leaf area index.

The number of nodes was associated with ground cover and leaf area of soybeans at 5 weeks; and the number of pods was correlated with

Table 27. Simple correlation coefficients among variables from experiment 2

Variables	Soybean					
	Ground cover			Leaf area index		
	4 weeks	5 weeks	7 weeks	4 weeks	5 weeks	7 weeks
Sic. GC 4 wks	-.067 NS	-.083 NS	-.036 NS	-.071 NS	-.068 NS	-.099 NS
Sic. GC 5 wks	-.057 NS	-.093 NS	-.018 NS	-.038 NS	-.055 NS	-.061 NS
Sic. GC 7 wks	-.198 NS	-.220 *	-.090 NS	-.172 NS	-.150 NS	-.118 NS
Sic. LA 4 wks	-.071 NS	-.091 NS	-.042 NS	-.082 NS	-.063 NS	-.107 NS
Sic. LA 5 wks	-.042 NS	-.088 NS	-.065 NS	-.035 NS	-.040 NS	-.001 NS
Sic. LA 7 wks	-.181 NS	-.227 *	-.128 NS	-.153 NS	-.161 NS	-.129 NS
Soy. GC 4 wks	---	.428 **	.371 NS	.910 **	.368 **	.339 **
Soy. GC 5 wks	.428 **	---	.637 **	.499 **	.921 **	.696 **
Soy. GC 7 wks	.371 **	.637 **	---	.367 **	.581 **	.832 **
Soy. LA 4 wks	.910 **	.499 **	.367 **	---	.469 **	.393 **
Soy. LA 5 wks	.368 **	.921 **	.581 **	.469 **	---	.678 **
Soy. LA 7 wks	.339 **	.696 **	.832 **	.393 **	---	---
Sic. plants/ha	-.092 NS	-.223 *	-.020 NS	-.097 NS	-.179 NS	-.052 NS
Soy. branches	-.184 NS	-.228 *	-.217 *	-.178 NS	-.208 *	-.133 NS
Soy. nodes	-.224 *	.204 *	.195 NS	-.108 NS	.247 *	.258 *
Soy. leaves	-.119 NS	-.176 NS	-.284 **	-.107 NS	-.146 NS	-.233 *
Soy. height	.270 **	.529 **	.506 **	.326 **	.569 **	.622 **
Soy. no. pods	.137 NS	.156 NS	.237 *	.216 *	.189 **	.327 **

Table 27. Continued

Variables	Sicklepod		Soybean		
	No. plants	No. branches	No. nodes	No. leaves	Stem height
Sic. GC 4 wks	.570 **	-.236 *	.151 NS	-.325 **	.238 *
Sic. GC 5 wks	.596 **	-.235 *	.175 NS	-.379 **	.345 **
Sic. GC 7 wks	.793 **	-.365 **	.165 NS	-.463 **	.302 **
Sic. LA 4 wks	.575 **	-.199 NS	.143 NS	-.295 **	.239 *
Sic. LA 5 wks	.637 **	-.268 **	.177 NS	-.413 **	.385 **
Sic. LA 7 wks	.733 **	-.307 **	.147 NS	-.450 **	.269 **
Soy. GC 4 wks	-.092 NS	-.184 NS	-.224 *	-.119 NS	.270 **
Soy. GC 5 wks	-.223 *	-.228 *	.204 *	-.176 NS	.156 NS
Soy. GC 7 wks	-.020 NS	-.217 *	.195 NS	-.284 **	.506 **
Soy. LA 4 wks	-.097 NS	-.178 NS	-.108 NS	-.107 NS	.326 **
Soy. LA 5 wks	-.179 NS	-.208 *	.247 *	-.146 NS	.569 **
Soy. LA 7 wks	-.052 NS	-.133 NS	.258 *	-.233 *	.622 **
Sic. plants/ha	---	-.452 **	.012 NS	-.535 **	.217 *
Soy. branches	-.452 **	---	.150 NS	.846 **	-.148 NS
Soy. nodes	.012 NS	.150 NS	---	.127 NS	.441 **
Soy. leaves	-.535 **	.846 **	.127 NS	---	-.235 *
Soy. height	.217 *	-.148 NS	.441 **	-.235 *	.320 **
Soy. no. pods	.023 NS	.319 **	.320 **	.293	.324 **

soybean ground cover and leaf area at 7 weeks.

Number of pods per plant was correlated with the soybean characteristics -- branches, nodes, leaves, and height. Number of branches with number of leaves were highly associated; as well as number of nodes with height were positively correlated. A negative association existed among height and number of leaves.

DISCUSSION

Sicklepod

Ground Cover and Leaf Area Index

Sicklepod growth, as measured by leaf area index and percentage ground cover was faster in experiment 1 than in experiment 2, although higher weed densities were present in experiment 2 than in experiment 1. Four weeks after planting, ground cover and leaf area of sicklepod were generally higher in experiment 1 than in experiment 2. And, these parameters were about the same for experiment 1 at 6 weeks in comparison with experiment 2 at 7 weeks after establishment.

This was probably due to differences in emergence time of sicklepod, since the weed germinated more rapidly and uniformly from the natural infestation of experiment 1 than in experiment 2, where sicklepod was seeded over the area and the seeds remained closer to the surface, where the soil dried out more quickly, resulting in delayed and variable germination.

As compared to the growth during the first 4 weeks, sicklepod growth for the period from 4 to 6-7 weeks was very rapid. Oliver (1974) also found that morningglory populations under intraspecies competition had a rapid increase in leaf area index between 4 and 6 weeks in comparison to soybean leaf area index under intraspecies competition.

In experiment 1, negative correlation coefficients were generated between sicklepod leaf area index and ground cover at 6 weeks and soybean leaf area and ground cover at 4 weeks, but not at 6 weeks. And, in experiment 2, negative correlations occurred between sicklepod leaf area and ground cover at 7 weeks with soybean ground cover at 5 weeks, but not at 7 weeks.

This means that soybeans in narrow row spacings were affecting sicklepod growth, mainly the 30-cm row treatments, which remained until 5 weeks. After 5 weeks, when rows from the variable pattern treatments had been removed, the correlations previously referred to tended to lose significance, meaning that the negative relationships between sicklepod and soybean growths disappeared. That suggests that soybeans in 30-cm rows are more likely to outcompete sicklepod if left for an extended period of time, probably during the whole season.

Mannering and Johnson (1969) confirmed that soybeans in 18-cm rows were especially effective in providing early cover. They found that almost 80% of the soil was covered as early as 5 weeks after planting; and that soybeans in 100-cm rows never completely filled the between-row area.

Dry Weight

Sicklepod dry weight per area was not associated with soybean leaf area and ground cover at 4 weeks in experiment 1; however, it was negatively correlated with leaf area and ground cover of soybeans at 6 weeks. This corroborates that the establishment of the variable row pattern modified the competition relationships, favoring sicklepod growth by creating additional space between soybean rows.

Sicklepod dry weight per unit area increased rapidly with increasing weed density, and then tended to level off at the high population. Since at high sicklepod populations further increases in the number of plants did not lead to correspondingly increases in dry matter produced per area, heavy intraspecific competition should have occurred.

Ervio (1971) also reported that dry matter yield of Chenopodium album L. per unit area increased with an increase in density up to a ceiling value. Thereafter, the yield remained almost constant even when there was an increase in the number of plants per unit area.

Sicklepod size, as determined by the dry weight per plant, followed the opposite direction, decreasing steadily with the increase in weed density. Ervio (1971) stated that when plants are subjected to competition there is a decrease either in the size or number of plant parts or in both of these, with a consequent decrease in weight per plant. The specimen plants are heaviest when growing at lowest density, and their weight is reduced as available growing space decreases.

Soybean

Ground Cover and Leaf Area Index

Through the measurements of leaf area index and ground cover of soybeans at 4 weeks after planting in both experiments, and also of soybean dry matter at 5 weeks, no effects of sicklepod competition on soybean appeared to be occurring until these stages.

Buchanan and Burns (1971) reported that most crops will tolerate some growth early in the season without suffering yield reductions.

Thurlow and Buchanan (1972) stated that soybeans withstand approximately

4 weeks of early weed competition. Nevertheless, these workers reported that in Alabama soybean yields were reduced in some instances when sicklepod competed for 4 weeks with soybeans.

Interactions in experiment 2 between sicklepod densities and soybean row distances for soybean ground cover and leaf area index may have resulted from the high initial variability in sicklepod stands, originated by lack of uniform weed germination.

After soybean rows were cut from the variable 30-cm treatments to establish row spacings equivalent to the constant row system, leaf area index and ground cover of soybeans in the variable pattern were generally lower than for soybeans in the constant pattern. This suggests that soybean plants in 30-cm rows at that stage were adapting themselves in relation to this close row spacing and even starting to suffer some intraspecific competition. However, since the final seed yields obtained from the variable row pattern tended to be higher as compared to the constant pattern, the thinning of these soybean rows certainly was later compensated in terms of leaf area produced and solar energy intercepted.

Donald (1961) showed the recovery of leaf area index after reduction by thinning and defoliation in clover. When the control had approached the ceiling value and its crop growth-rate had declined, the thinned plots still had a leaf area index which permitted rapid crop growth; and all treatments were of similar leaf area index at the end.

Although the differences in soybean leaf area index and ground cover were quite pronounced for the various row widths, at the end the treatments showed uniformity in regard to seed yields.

Hicks et al. (1969) reported that leaf area index increased as soybean plant population increased. Weber et al. (1966) also reported that high soybean populations resulted in substantial increases in the rate of leaf area index accumulation. As row width increased, leaf area index accumulation decreased. Wide rows accumulated leaf area index at a slower rate than the narrow row widths.

Jeffers and Shibles (1969) stressed that in a high radiation environment, maximum yield might be achieved by a genotype capable of producing leaf area at the fastest rate. But, cultural practices and field problems may limit leaf production in soybeans to less than critical leaf area index.

Weber et al. (1966) reported that high plant populations and narrow row spacings favored a rapid attainment of high leaf area index and presented the greatest dry weight accumulation. However, there was little relationship between yield and dry weight accumulation.

Sakamoto and Shaw (1967b) showed that although soybean leaf area increased from flowering to pod-formation, net photosynthesis did not increase correspondingly; net photosynthesis decreased even though the leaf area index increased from initial flowering to pod-formation. This may be interpreted to mean that the maximum effective leaf area index was attained at initial flowering. Buttery (1969b) found that increase in leaf area index from 0.3 to 1.0 was associated with a marked decrease in net assimilation rate. There was no optimum value of leaf area index. Net assimilation rate was affected by leaf area index even below a value of 1.

Plant Characteristics

In experiment 1 only the higher weed densities decreased the number of branches and the number of nodes per soybean plant; while in experiment 2 the number of branches and the number of leaves per soybean plant were also affected only by the higher sicklepod infestations. In both experiments, main stem height of soybeans was not affected at all by any of the weed levels, and neither was the number of nodes in experiment 2.

Investigations by Weber and Staniforth (1957), Knake and Slife (1962), and McWhorter and Hartwig (1972) revealed little or no effect of weeds on height of soybeans. Eaton et al. (1976) found that weed competition reduced the number of nodes per soybean plant.

Since determinate-type cultivars, like "Bragg," will essentially complete their vegetative growth prior to flowering; those plant characteristics were all well set by the time the reproductive period developed. Therefore, the level of competition between sicklepod and soybean during the vegetative growth period was lower as compared to the competitive effects registered later in the season, after the reproductive stages of soybean had begun.

Knake and Slife (1969) also reported that the greatest competitive effect of giant foxtail with soybeans occurred after the reproductive stage of soybean began or after the weeds became sufficiently dense to reduce the light which soybeans received. That soybeans competed well with foxtail early in the season but with foxtail overtopping the soybeans, the effect of late competition in soybeans was quite pronounced. Barrentine (1974) reported that of the maximum soybean yield reduction

caused by common cocklebur, half occurred during the vegetative growth stages, and half during the reproductive growth stages.

Some differences between the two experiments occurred for soybean plant characters as a result of sicklepod competition. In experiment 1, stem diameter was the soybean plant characteristic most negatively correlated with the sicklepod variables, followed by the number of branches. In experiment 2, number of leaves was the character most negatively associated with the sicklepod variables, followed by the number of branches. The number of nodes of soybeans from experiment 1 was negatively associated with sicklepod parameters, while the number of nodes of soybeans from experiment 2 was not correlated with the weed. Stem height of soybeans from experiment 1 was not correlated with sicklepod; however, sicklepod and soybean height in experiment 2 were positively related.

In both experiments stem height and number of nodes were positively correlated. On the average, soybeans from experiment 1 were about 20 cm taller than the plants from experiment 2.

Since in experiment 1, height of soybean stems tended to be depressed by sicklepod, while in experiment 2 height of soybean stems tended to be enhanced by sicklepod competition, it is suggested that the differential growth rates of soybeans as well as of sicklepod due to the two distinct planting dates might have influenced these apparently divergent responses.

Analysing the number of branches per soybean plant in both experiments, it is observed that the variable row distances of 90 and 60 cm showed equivalent data, as contrasted with the significant differences detected between the same spacings in the constant row pattern.

Similar behavior is noted for number of leaves per soybean plant in experiment 2. Also, in experiments 1 and 2 the values obtained for stem height of soybeans at the variable rows pattern were always lower than for soybeans in equivalent row distances at the constant rows system.

This signifies then that intraspecific competition in soybeans at 30-cm rows occurred during the first 5 weeks after planting, and was reflected in the mentioned characteristics. Therefore, number of branches, number of leaves, and stem height were well defined early in the growing cycle in response to the various row width treatments. Because even when the narrow rows were changed to wider spacings, there were no such corresponding alterations in these attributes.

The 30-60-cm rows treatment reflected on plant characters a longer and heavier competition between soybean rows, since only part of the initial 30-cm pattern was removed at 5 weeks.

Buttery (1969a) emphasized that high-density planting of soybean results in small plants, while low density produces larger plants. Buttery (1969b) also found the young soybean plant very responsive to small alterations in level of light received.

Doss and Thurlow (1974) concluded that after the first month of growth, plants of the higher population tended to grow slightly faster than those on low population plots, primarily because of longer internodes of plants in high population plots.

Contrary to the previously discussed plant characteristics, stem diameter was affected even by the low sicklepod density. And, stem diameter of soybeans in the variable row pattern followed closely the values obtained for the plants at the constant row pattern. These two

indications suggest that the stem thickness was slowly modified during the growing season. It received little influence by the early intracompetition of soybeans in 30-cm rows during the first 5 weeks of the season. However, it was affected by all sicklepod densities, presumably then, due to weed competition later in the soybean cycle. Buttery (1969a) found the effects of high density of soybean more obvious with latter samples, indicating that competitive stress increased with growth of the plants.

The results obtained in my experiments suggest decreasing numbers of branches and leaves, decreasing stem diameter, and increasing height of soybean plants as row spacing is reduced or plant population is increased.

Weber et al. (1966) determined that plant height tended to increase at the higher population densities, and number of branches per plant increased as plant density decreased. Hicks et al. (1969) also affirmed that plant height increased with narrower row spacings; and stem diameter decreased as seeding rates increased. Major and Johnson (1974) reported that final plant height and internode number increased as light intensity increased. Final plant height was one of a few plant characters on which an effect of light intensity was detected for all cultivars. And, a significant increase in the number of internodes with increased light intensities was observed for some cultivars.

Lehman and Lambert (1960) concluded that the number of branches increased as spacing was increased. Basnet et al. (1974) determined that the production of branches and pods on branches was suppressed in narrow spacing between or within rows. However, higher plant density in the narrow spacing more than compensate for more branches in wider

spacing. Weber et al. (1966) found that increased branching is related mainly to the lack of plant competition. It appears that branching is not a critical factor in maximum yield production, since the highest yields were obtained at relatively low branch frequency.

Seed Yield and Components of Yield

In general, correlation coefficients among soybean and sicklepod variables tended to increase with advance of the growing season, while coefficients of variation for sicklepod parameters showed the tendency to decrease. These patterns seem to indicate that the variability of the community is very high at the beginning, and that at the end the community stabilizes. Or conversely, the predictability of what is going to occur with soybean yield as a result from sicklepod competition is low when the growing season starts, and increases toward soybean maturity. However, this trend is of limited value, since weed control measures require an early and precise estimation of damage.

In this sense, weed density may be a better indicator than weed dry weight because that can be estimated sooner. Dry matter yield of the weed is obtained at the end of the growing season, when it is too late for any control measure to be applied. Nevertheless, correlation coefficients and coefficients of determination generally have been higher for weed dry matter than for weed density. Therefore, crop yield is better predicted by the actual growth made by the weeds, expressed as dry weight, rather than by the number of weeds per unit area. Thurlow and Buchanan (1972) found the weight of sicklepod at harvest a more precise indicator of soybean yield reduction than the number of sicklepod plants per unit area.

In this investigation, the quadratic model generally fit the data better than the linear regression model. However, Thurlow and Buchanan (1972) obtained good fitting of their data by using the linear model. It is possible that sicklepod placement might have provided different competition stresses on the soybean in the two experiments. Thurlow and Buchanan (1972) planted sicklepod seeds in the row and over the soybean seed at the time of planting, using row distances of 105 cm, while in my experiment 1, sicklepod was randomly distributed over the entire area and rows were spaced from 45 to 90 cm.

Thurlow and Buchanan (1972) emphasized that sicklepod planted in the drill usually was less competitive with soybeans than when planted 15 cm or more from the drill. Sicklepod in the drill row does not compete with soybeans as well as when it is between the rows. Probably in their studies interspecific competition was severe from the beginning, while in our investigation intraspecific competition might have played a major role initially.

During soybean development, the reproductive stages were severely influenced by the occurrence of sicklepod. The number of pods, the number of seeds, and seed weight per soybean plant were the yield components most affected by sicklepod competition. These yield components were about equally reduced, with number of pods showing a tendency of being slightly less affected than the number of seeds. On the average, the numbers of pods and seeds, and seed yield per plant decreased approximately 43 to 68%, depending on the weed density. The number of seeds per pod was relatively less suppressed by the presence of sicklepod. And, seed size was almost unaffected by the weed; however, it tended to increase under the sicklepod infestations.

These results compare with other investigations previously reported. Kuake and Slife (1962), Burnside and Colville (1964a), Moolani et al. (1964), Berglund and Nalewaja (1969), and Nave and Wax (1971) reported decreases in number of pods per soybean plant as a result from weed infestations. Staniforth (1958), Burnside and Colville (1964a), Berglund and Nalewaja (1969), and Hammetton (1972) found reduced seed production per soybean plant due to weed competition.

Staniforth (1958), Burnside and Colville (1964a), and Berglund and Nalewaja (1969) reported decreases in number of seeds per pod for soybeans competing with weeds. And, Weber and Staniforth (1957), Burnside and Colville (1964a), Berglund and Nalewaja (1971), and Nave and Wax (1971) found little effect of weed competition on soybean seed size.

However, Eaton et al. (1976) mentioned that pods per soybean plant has been the major component of seed yield reduced by weed competition in other studies. Eaton et al. (1973) also found that the influence of weed competition on pod numbers can result from fewer flowers produced, increased flower abortion, or abortion of newly initiated pods. And, that as the number of soybean pods per plant is reduced, soybean seed weight increases, although total seed yield decreases. Soybeans produce larger seeds with fewer pods when weed competition is early in the growing season.

Hinson and Hanson (1962) considered that during flowering and early ovule and seed development the soybean plant regulates, by physiological abortion, the number of seeds it can fill under existing environmental conditions. Thus, when unfavorable conditions occur early in the season, the plants are smaller and less seed are set. Subsequent favorable conditions providing abundant food for those seed

set tend to produce larger seeds than would be produced if the reverse condition occurred.

For experiment 2, no differences were found in relation to the number of pods per soybean plant. It is assumed that the countings were made at an early stage of pod formation and development. Many newly formed pods might have already dropped soon after the insects started their attack, but before the samples were selected from the plots.

Soybean seed yields were reduced 47 to 73% as a result of the sicklepod densities. These values are higher than for the previously reported yield components, but they may reflect some losses occurring during the threshing and cleaning of the seeds. Soybean plants under sicklepod infestations did not mature uniformly, and the seeds contained a high moisture content which required the plants to be dried prior to threshing.

These yield reductions were higher than those reported by Thurlow and Buchanan (1972). They found that sicklepod densities of 7.7 weeds/m² did not reduce soybean yields more than 35% in Alabama. It may be that environmental conditions are more favorable for sicklepod growth in Florida than in Alabama.

The trend in yield reduction from my experiment (47, 65, and 73% for the low, medium, and high weed densities, respectively) agrees with the conclusion of Shadbolt and Holm (1956) that sparse weed stands causes almost as much damage as much denser stands. Also, Wilson and Cole (1966) reported that soybean yields were decreased at a slower rate as the number of morningglory plants was increased from a certain density.

Although the soybean yield components in general were higher for plants in the wider row spacings in comparison with the narrower widths, it is observed that seed yield per unit area increased in the opposite direction, i.e., lower yields occurred at the 90-cm row distances. Therefore, in this study the soybean population per unit area was relatively predominant over yield per plant. Also, the soybean density of one plant per 8.5 cm of row may be considered low, especially in 90-cm rows. As a result, the soybean population per area at this wide row distance might have been lower than desirable.

Wiggans (1939) emphasized that spacings greater than 7.5 cm within the row show significantly smaller yields than the thicker rates. However, Hartwig (1957) showed that rate of planting studies with different varieties and strains of soybeans have shown little difference in the optimum planting rate in the row. And, Lehman and Lambert (1960) also found that the effects on yield of spacing within rows were variable. Yield at no one spacing within row seemed greater than at any other spacing.

Nevertheless, the final soybean seed yields were quite constant, independent of row distances or populations per area, and the practice of constant or variable rows during the season.

Pandey and Torrie (1973) reported that seed yield, an extremely complex character, is the result of many growth functions of the plant. It is an example of integration in which the components of yield are partially interdependent in their development.

Our results on soybean yield components and seed yield generally agree with those reported in the literature. Lehman and Lambert (1960), Weber et al. (1966), Hicks et al. (1969), and Basnet et al. (1974)

reported that the components pods per plant and seeds per plant increased with the decrease in plant population per unit area. Lehman and Lambert (1960) and Weber et al. (1966) found that soybeans per pod were less affected by changes in spacing. And, Probst (1945), Lehman and Lambert (1960), Weber et al. (1966), and Basnet et al. (1974) reported little effect of spacing on soybean seed size.

Weber et al. (1966) confirmed that plants produced at high densities are taller, more sparsely branched, and set fewer pods and seeds than those plants at low densities. Thus, the seed yield reduction resulting suggests more severe plant competition at higher plant densities. On the average, seed yields are low in wide rows and are attributed to greater intra-row and lesser inter-row plant competition.

Pandey and Torrie (1973) determined that pods per unit area and seeds per pod had the greatest effect on seed yield in their experiments. Coefficient analysis showed that both pods per area and seeds per pod were important factors in determining seed yield, and that seed weight was relatively unimportant. Lehman and Lambert (1960) mentioned that if the components of yield are taken as a unit it can be concluded that all are to some extent responsible for the plant's ability to adjust to differences in spacing. They found the soybean to have the ability to compensate for differences in density. Compensation was accomplished primarily through number of pods per plant.

Hinson and Hanson (1962) reported that the failure of a plant to regulate accurately the number of seeds it can fill is associated with changes in average seed weight. One of the primary reasons for average seed weight not responding equally to spacing treatments is the failure of the plants to equally regulate the number of developing ovules they

retain in proportion to the number of seeds they can fill.

Lehman and Lambert (1960) affirmed that certain plant characters, such as seeds per plant, pods per plant, and branches per plant, react in a similar manner when the spacing arrangement is changed; that is, the number of units of these characters increases as the plant population decreases. On the other hand, characters such as weight per 100 seeds and seeds per pod do not follow any particular pattern. It is evident that seeds per plant and pods per plant tend to react in a similar manner. However, seed weight and seeds per pod react independently of the other two components and of each other, in most cases.

Weber et al. (1966) recommended that under conditions of higher productivity, seed yield is maximized with wider plant spacings. Conversely, with lower productivity, more stringent environments, or both, maximum seed yield is obtained at narrower plant spacings.

Wiggans (1939) concluded from his studies that narrowing the distance between rows until the distance between rows equals the space between plants in the row would give the greatest yield. Basnet et al. (1974) stressed that their results with yield indicate that changing row spacing itself has no effect on yield. Yield differences include differences caused by varying row width as well as planting rate. Thus, as row-width is narrowed, within-row spacing should be increased.

If the ultimate objective of soybean culture is only seed production, probably there is little advantage in planting soybean in the south at row spacings narrower than 90 cm. Closer rows require more seed at planting, and additional area for sicklepod growth is provided within soybean rows, where it is difficult to control by cultivation.

However, development of efficient herbicides for control of sicklepod and other dicotyledonous weeds in soybean adds significance to narrow row distances as a cultural practice to complement chemical weed control. And, in addition to equivalent or better seed yields than soybeans in wide rows, close row widths offer the possibility of obtaining a forage crop during soybean vegetative stages.

The heavy initial soybean population, by occupying advantageously the space, provides more competition with weeds during the critical period of 4 to 6 weeks, especially if the weed density is low or if they are low-growing plants.

Wax and Pendleton (1968) reported that soybeans in narrow rows provide more control of weeds by shading than soybeans in wide rows. They consider that tall broadleaf weeds present a far more serious problem than uncontrolled, short broadleaf weeds, because of the shade canopy produced by soybeans.

Soybean was able to withstand some weed competition when sicklepod was present at the lowest level. At this density the size of sicklepods, as determined by dry weight per plant, was more depressed by soybeans in the closer row distances or higher populations. Barrentine (1974) also concluded that apparently soybeans can compete with relatively low common cocklebur densities without significant yield reduction.

Kust and Smith (1969) explained that improved weed control in narrow rows may be due partially to absorption by soybean leaves of light wavelengths that may be most favorable for photosynthesis and vegetative growth of some weed species, and that complete canopies are not obtained for wide row widths. Therefore, the soybean leaf may act to reduce photosynthesis of weeds growing below it by absorbing

wavelengths of light used most efficiently by the weed plant for photosynthesis and for vegetative growth. Hartwig (1957), however, considered that adapted southern varieties have much heavier foliage than northern varieties and will normally completely fill the row middles in 90- to 100-cm rows.

By examining the regression lines obtained for soybean seed yield components as a function of plant population or row distances, it is seen that the differences were greatest under weed-free conditions. That is, when sicklepod was absent, soybean plants at 90-cm rows could express their greatest yield potential. Then, with increased levels of sicklepod, these yield components per soybean plant gradually tended to equalize, regardless of plant population or row width, principally when the weed densities were high. This implies that the plants from the low soybean population or from rows widely distanced were those that experienced the greatest reductions due to sicklepod competition.

Germination and Growth of Seedlings

Further tests about germination of soybean seeds and weight of the seedlings showed that these responses were positively correlated with weight of 100 seeds. Heavier seeds contain more reserves. Ogren and Rinne (1973) stressed that the development of the soybean seedling is dependent on the food reserves stored in the cotyledons. Good seed quality is necessary for a high percentage of germination and the subsequent development of the soybean seedling.

Seed germination and seedling vigor were also associated with soybean height. Although soybean seed yield and other yield components were not associated with plant height, number of seeds per pod and

weight of 100 seeds were highly correlated with stem height. Therefore, as heavier seeds were related with taller plants, stem height indirectly affected seedling germination and growth.

It is probable that seeds on taller plants encountered better maturity conditions, especially faster drying circumstances than seeds on shorter plants, which were also the most branched. Ogren and Rinne (1973) emphasized that the prior history of the seed before storage affects seed quality in soybean seeds. And, Pendleton and Hartwig (1973) referred that weather conditions during maturation and harvesting affect seed quality.

Nature of Sicklepod and Soybean Competition

In my experiments, water and mineral nutrients might be considered of less importance in determining the pattern of competition between soybeans and sicklepod. Since soil fertility was generally high, and water was not very limiting due to supplemental irrigation, competition for these two factors probably caused little reduction in soybean growth and yield. Light, then, might be considered the principal environmental factor for which soybean and sicklepod competed, once the weed overtopped and seriously shaded the crop at flowering.

Doss and Thurlow (1974) affirmed that soybean plants can show severe signs of water stress by wilting and by slow rate of growth or reduced plant growth, but when soil water is replenished, the plants appear to recover quickly. This is especially true during vegetative growth. Severe water stress does not appear to have as lasting or damaging effect on soybeans as on some crops except during pod-fill periods.

In view of the adequate rainfall pattern and the high fertility of the soil, it is unlikely that the suppressive effects of the sicklepod on soybean yield can be attributed to the inability of the soybeans to obtain sufficient mineral nutrients and water.

In experiment 1 soybean and sicklepod seedlings emerged simultaneously. Their growth rate was similar until mid-season, when sicklepod surpassed soybeans in height and formed a dense canopy over the soybeans. Soybean plants reached an average height of 87 cm. Sicklepod plants exceeded soybean plants in height after 10 weeks and reached a maximum height of 195 cm. Therefore, sicklepod intercepted a great portion of solar radiation falling on the field. Hicks et al. (1969) considered lack of light penetration into soybean canopies to be a major factor affecting seed yield.

Bowes et al. (1972) confirmed that the saturation light intensity of field-grown soybean is approximately equal to the maximum light intensity under which they are grown, indicating that soybeans acclimate to the light environment. Therefore, leaves from soybeans grown at the lowest intensity saturate at the lowest intensity, and have the lowest maximum rate of photosynthesis. Conversely, leaves from plants grown at the highest intensity saturate at the highest intensity, and have the highest maximum rate of photosynthesis.

Shibles and Weber (1965) stressed that rate of dry matter production is a linear function of percent solar radiation interception; i.e., energy fixed is in direct proportion to energy interception by the community. The direct correspondence between rate of dry matter production and the interception of solar energy, and the dependence of the latter on leaf surface production, have important implications with

respect to spacing and arrangement of plants in intertilled species such as soybeans.

Shibles and Weber (1966) again emphasized that dry matter production in equidistantly spaced soybeans is a linear function of solar radiation interception. Sequentially, as growth progresses, increasing leaf area development results in increasing occupancy of interplant spaces and, consequently, increasing percent solar radiation interception which, in turn, results in an increasing rate of dry matter production.

Shaw and Weber (1967) reported that present day soybean canopies intercept most of the solar radiation falling on the canopy in the outer periphery. Sakamoto and Shaw (1967a) reported that light interception and distribution through the profile of a plant community is postulated to contribute a dominant role to crop productivity. They determined that light interception by a field soybean community occurred primarily at the periphery of the canopy. When the open space between rows closed or when it was nearly closed, interception was primarily at the top of the canopy. Approximately 90% of the light was intercepted near the top and periphery of the soybean canopy.

Taylorson and Borthwick (1969) reported that the quality of leaf-filtered radiation is altered as a result of light absorption by chlorophyll.

Therefore, these investigations demonstrate that the soybean plant is very sensitive to variation and reduction in solar radiation being distributed over the canopy. Sicklegod plants growing taller than the soybeans, probably acted like a filter, reducing considerably the quantity and altering the quality of light transmitted through its foliage.

SUMMARY AND CONCLUSIONS

Full-season competition of sicklepod with soybeans induced many agronomically undesirable effects on the production of this crop.

While during the first month after soybean planting sicklepod growth was slow, it increased rapidly afterward. Sicklepod and soybean presented similar growth during the vegetative stages of the crop; however, after the reproductive stages of soybean began, sicklepod exceeded the crop in height and formed a dense canopy over soybeans.

Radiant energy is thought to be the major environmental factor limiting for soybeans after sicklepod overtopped and shaded the crop plants.

For the first month of growth no deleterious effects of sicklepod on soybeans were measured, suggesting that interspecific competition was insignificant during this period. Also, determinations taken for plant characters indicated that the soybean was able to withstand competition from the lowest levels of sicklepod during the vegetative growth stages.

However, even the lower sicklepod densities competed severely with soybean during its reproductive stages, reducing significantly most of the yield components and seed yield of the crop.

The capacity of sicklepod plants to compensate for available space, made this weed a strong competitor with soybeans at all densities investigated.

With weeds such as sicklepod that grow considerably taller than soybeans, limited success can be expected by varying row spacing alone. However, this practice should be considered an integral measure to complement other methods of sicklepod control.

The investigation also showed that areas where the length of the growing season is not severely limited by environmental factors, present the choice of planting a late maturity soybean cultivar at close row spacing in a variable pattern to obtain a forage crop after the first month of growth without any decreases on the final seed yields.

1. Influences of sicklepod densities

1.1. Plant characteristics:

1.1.1. As a result of sicklepod competition, soybean plants were less branched, set fewer leaves, and had smaller stem diameter than weed-free soybeans;

1.1.2. In one of two experiments, the number of nodes on the main stem decreased for soybeans under weed infestations;

1.1.3. Height of soybean plants was not affected by the occurrence of sicklepod.

1.2. Yield components and seed yield:

1.2.1. The yield components--number of pods, number of seeds, seeds per pod, and seed yield per soybean plant--were all reduced from sicklepod competition;

1.2.2. Soybean seed yields per unit area were significantly diminished by increasing levels of sicklepod infestation.

2. Effects of soybean row distances

2.1. Plant characteristics:

2.1.1. Number of branches, number of leaves, and stem

diameter of soybean plants decreased as row distance decreased;

2.1.2. Soybean height increased with narrowing of row width.

2.2. Yield components and seed yield:

2.2.1. The components of soybean yield--number of pods, number of seeds, and seed yield per plant--diminished as row spacing was reduced. Maximum difference between row widths for these components was attained for soybeans under weed-free conditions;

2.2.2. Generally, as row width decreased, soybean seed yield per unit area increased. Specifically, soybeans in 90-cm rows, either in constant or variable rows pattern, yielded less than soybeans in 60- and 30-60-cm rows in a variable pattern.

3. Other conclusions

3.1. The various degrees of sicklepod and soybean populations did not affect the soil contents of phosphorus, potassium, calcium, and magnesium;

3.2. No effects of sicklepod densities nor of soybean row distances were detected for seed germination and seedling vigor for the next soybean generation.

The experiments reported are not definitive. It is indicated, as suggestions for future research, that more investigations are needed to establish the effect of very low sicklepod densities on the soybean production, to compare the competitiveness of different soybean cultivars with sicklepod, to investigate the relations of soybean planting date and sicklepod growth, and to determine the influences of sicklepod on soybean seed quality and on soybean seedling diseases on the next generation.

APPENDICES

APPENDIX A

Appendix A-1. Analysis of variance--mean squares, experiment 1

Source	df	Percentage ground cover		Leaf area index	
		4 weeks	6 weeks	4 weeks ^a	6 weeks
Sicklepod					
Blocks	3	8.4495	135.9988	0.4141	0.05875
Density (D)	3	774.2056 ^b	4576.8754 ^b	11.2356 ^b	1.10023 ^c
Error (a)	9	22.5873	95.4919	0.4114	0.05371
Rows	5	37.2002	350.7097 ^b	0.1817	0.07531 ^b
D x rows	15	20.2163	72.5312	0.4607	0.02949
Error (b)	60	45.6728	93.4666	0.6211	0.02121
Soybean					
Blocks	3	168.56	681.65 ^c	0.05604	0.4906 ^c
Density (D)	3	108.76	486.72	0.07052	0.3032
Error (a)	9	117.80	169.20	0.06161	0.1091
Rows	5	7488.52 ^b	3741.99 ^b	2.11651 ^b	1.7374 ^b
D x rows	15	107.01	118.20	0.05100	0.1156
Error (b)	60	165.74	150.31	0.07016	0.1182

^aMean squares must be multiplied by 10⁻²^bSignificance at the 1% level.^cSignificance at the 5% level.

Appendix A-1. Continued

Soybean plant characteristics						
Source	df	No. branches	No. nodes	Stem diameter	Stem height	Intern. length
Blocks	3	2.0395	5.6263 ^a	1.4858 ^a	193.1813 ^a	0.13094
Density (D)	3	12.9920 ^a	2.6540 ^b	7.6953 ^a	12.0290	0.19010
Error (a)	9	1.6258	0.4106	0.1644	13.3099	0.09295
Rows	5	10.2301 ^a	0.8469	1.3662 ^a	279.7983 ^a	1.12491 ^a
D x rows	15	0.5962	0.7582	0.2378	53.3082	0.18717 ^b
Error (b)	60	1.1322	0.5658	0.2072	38.5750	0.09177

Soybean yield components						
Source	df	Pods/plant	Seeds/plant	Seeds/pod	Seed wt./plant	Wt. 100 seeds
Blocks	3	345.8575 ^b	2,750.60 ^a	0.30250 ^a	70.9446 ^a	11.2197 ^a
Density (D)	3	10,458.9390 ^a	37,917.19 ^a	0.26322 ^a	607.1187 ^a	1.0987
Error (a)	9	85.8650	375.82	0.01118	5.9736	1.2093
Rows	5	654.6980 ^a	1,678.59 ^a	0.02146	29.7967 ^a	1.4191 ^b
D x rows	15	161.2402 ^b	532.62	0.02410	9.6254	1.9949
Error (b)	60	86.4296	335.67	0.01562	6.3987	0.9629

^aSignificant at the 1% level.^bSignificant at the 5% level.

Appendix A-1. Continued

Source	df	Sicklepod			Soybean		
		Dry weight		Per plant	Dry matter		Seed yield
		Per area	Per area		Per area	Per area	
Blocks	3	12,241,432	9,258.34 ^a		6,156		1,710,900 ^b
Density	3	159,067,120 ^b	91,783.05 ^b		26,747		25,023,961 ^b
Error (a)	9	4,134,190	2,048.89		17,105		104,467
Rows	5	2,761,132 ^a	400.60		1,535,818 ^b		401,432 ^b
D x rows	15	2,442,328 ^a	858.42 ^a		8,944		93,383
Error (b)	60	1,049,912	394.45		6,218		114,253

Source	df	Soil nutrients content				Soybean seedlings	
		Phosphorus	Potassium	Calcium	Magnesium	Germination	Fresh wt. ^c
Blocks	3	11,4819	662.6302	18,363	12,717 ^a	207.2049	5.0813 ^a
Density	3	3,2200	51.7151	3,170	5,618	93.3160	2.5135
Error (a)	9	10,8937	290.4448	6,144	2,059	118.7790	1.1995
Rows	5	6,9354	29,0607	1,628	1,472	70,8854	1.0814
D x rows	15	2,8203	16.3900	2,966	1,307	41.4410	1.2191
Error (b)	60	4,6220	30.9296	2,989	1,122	55.4688	0.9451

^a Significant at the 5% level.^b Significant at the 1% level.^c Mean squares must be multiplied by 10⁻².

Appendix A-2. Partition of soybean populations and soybean populations x sicklepod densities--
mean squares, experiment 1

Source	df	Sicklepod		Soybean		
		Dry weight		Yield components		
		Per area	Per plant	Seeds/pod	Wt. 100 seeds	
Final soy. popul. (FP)-Lin.	1	8,838,729 ^d	982.35	0.00620	1.8735	
Quadratic	1	5,985	65.99	0.02590	0.1722	
Initial soy. popul. (IP)	1	4,435,880 ^b	872.90	0.03682	4.5675 ^a	
FP x IP	2	262,533	40.87	0.01920	0.2412	
FP x Sic. densities (D)	6	4,613,170 ^a	1241.32 ^a	0.02904	4.0280 ^a	
IP x D	3	539,836	199.48	0.01635	0.9903	
FP x IP x D	6	1,222,731	805.00	0.02303	0.4642	
Error (b)	60	1,049,912	394.45	0.01562	0.9629	

Soybean

Source	df	Yield components		Seed yield		
		No. pods		Per area		
		No. pods	No. seeds	Seed wt./plant	Per area	
Final soy. popul. (FP)-Lin.	1	2314.8127 ^d	6802.13 ^d	131.4749 ^d	1,151,866 ^d	
Quadratic	1	26.3292	0.01	0.0383	448,340	
Initial soy. popul. (IP)	1	866,4017 ^a	1321.65	14.7816	328,068	
FP x IP	2	32.9732	134.58	1.3445	39,443	
FP x Sic. densities (D)	6	324,7626 ^a	1090.29 ^a	19.4646 ^b	47,142	
IP x D	3	109,5936	413.50	7.6836	154,120	
FP x IP x D	6	23,5409	34.51	0.7571	109,256	
Error (b)	60	86,4296	335.61	6.3987	114,253	

^aSignificant at the 1% level.^bSignificant at the 5% level.

APPENDIX B

Appendix B. Analysis of variance--mean squares, experiment 2

Source	df	Percentage ground cover			Leaf area index		
		4 weeks	5 weeks	7 weeks	4 weeks ^a	5 weeks ^a	7 weeks ^a
Sicklepod							
Blocks	3	20.2396 ^b	116.7103	401.94	0.2007	2.2512	0.13167 ^b
Density (D)	3	548.7550 ^b	1038.9202 ^b	5089.58 ^b	6.8807 ^b	19.6995 ^b	1.62262 ^b
Error (a)	9	64.5339	113.5341	175.62	0.6462	1.9179	0.09453
Rows	5	34.1419	67.1593	214.29	0.3241	1.1753	0.07937 ^c
D x rows	15	31.4467	65.9745	180.32	0.2743	1.3864	0.07505 ^c
Error (b)	60	28.6460	63.9587	104.33	0.3329	0.8791	0.03922
Soybean							
Blocks	3	214.77	216.71	517.74	0.09878	0.09622	1.2549 ^c
Density (D)	3	766.41 ^c	631.50	54.77	0.29540	0.24157	0.2265
Error (a)	9	249.55	206.50	239.94	0.13259	0.10276	0.2043
Rows	5	3810.10 ^b	1497.75 ^b	2900.79 ^b	0.84604 ^b	0.46903 ^b	1.8038 ^b
D x rows	15	272.31	296.47 ^c	320.39 ^b	0.10131	0.14338 ^b	0.2372
Error (b)	60	158.71	137.29	110.86	0.07169	0.05805	0.1526

^aMean squares must be multiplied by 10⁻².^bSignificant at the 1% level.^cSignificant at the 5% level.

Appendix B. Continued

Source	df	Soybean		
		Plant characteristics		No. pods/plant
		Dry matter	No. nodes	
		Per area		
Blocks	3	11,284	0.3682	829.1798
Density (D)	3	20,470	0.0060	38.1065
Error (a)	9	7,608	0.3189	251.8520
Rows	5	1,916,574 ^a	1.6847 ^a	36.8014
D x rows	15	9,290	0.3832	27.3782
Error (b)	60	5,260	0.3618	36.6444
Soybean				
Source	df	Plant characteristics		
		Plant characteristics		No. branches
		Stem height	No. leaves	
Blocks	3	364.7531 ^b	8.4818	0.3536
Density (D)	3	122.5458	129.1576 ^a	6.3125 ^a
Error (a)	9	93.0113	6.3259	0.4965
Rows	5	99.3734 ^a	113.5121 ^a	7.3917 ^a
D x rows	15	29.9536	6.2093	0.8675
Error (b)	60	23.7402	9.6388	0.6966

^aSignificant at the 1% level.^bSignificant at the 5% level.

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BIOGRAPHICAL SKETCH

Nilson Gilberto Fleck was born on March 30, 1945, in Taquara, Rio Grande do Sul, Brazil. In December of 1969, he received the degree of Engenheiro Agrônomo from the Federal University of Rio Grande do Sul, Porto Alegre, Brazil. In September 1973 he graduated from the same University with a Master of Science in Fitotecnia degree.

Since 1971 he has maintained the positions of Assistant Professor at the Department of Fitotecnia of the Federal University of Rio Grande do Sul, and of Research Agronomist at the Secretary of Agriculture of Rio Grande do Sul, Brazil. In both occupations his activities have been related to Weed Science.

In September of 1973 he was offered a scholarship by the Agency for International Development for a graduate program in Weed Science in the United States. Since that time he has been enrolled in the Graduate School of the University of Florida to pursue the degree of Doctor of Philosophy, with a major in Agronomy and a minor in Botany.

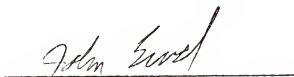
The author is a member of the Weed Science Society of America and the International Weed Science Society.

He is married to the former Marleni Rabelo de Oliveira, and they have one son, Alexandre.

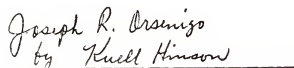
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Wayne L. Currey, Chairman
Associate Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.


John J. Ewel
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.


Joseph R. Orsenigo
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.


Earl G. Rodgers
Professor of Agronomy

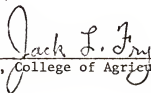
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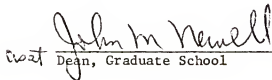
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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1976



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